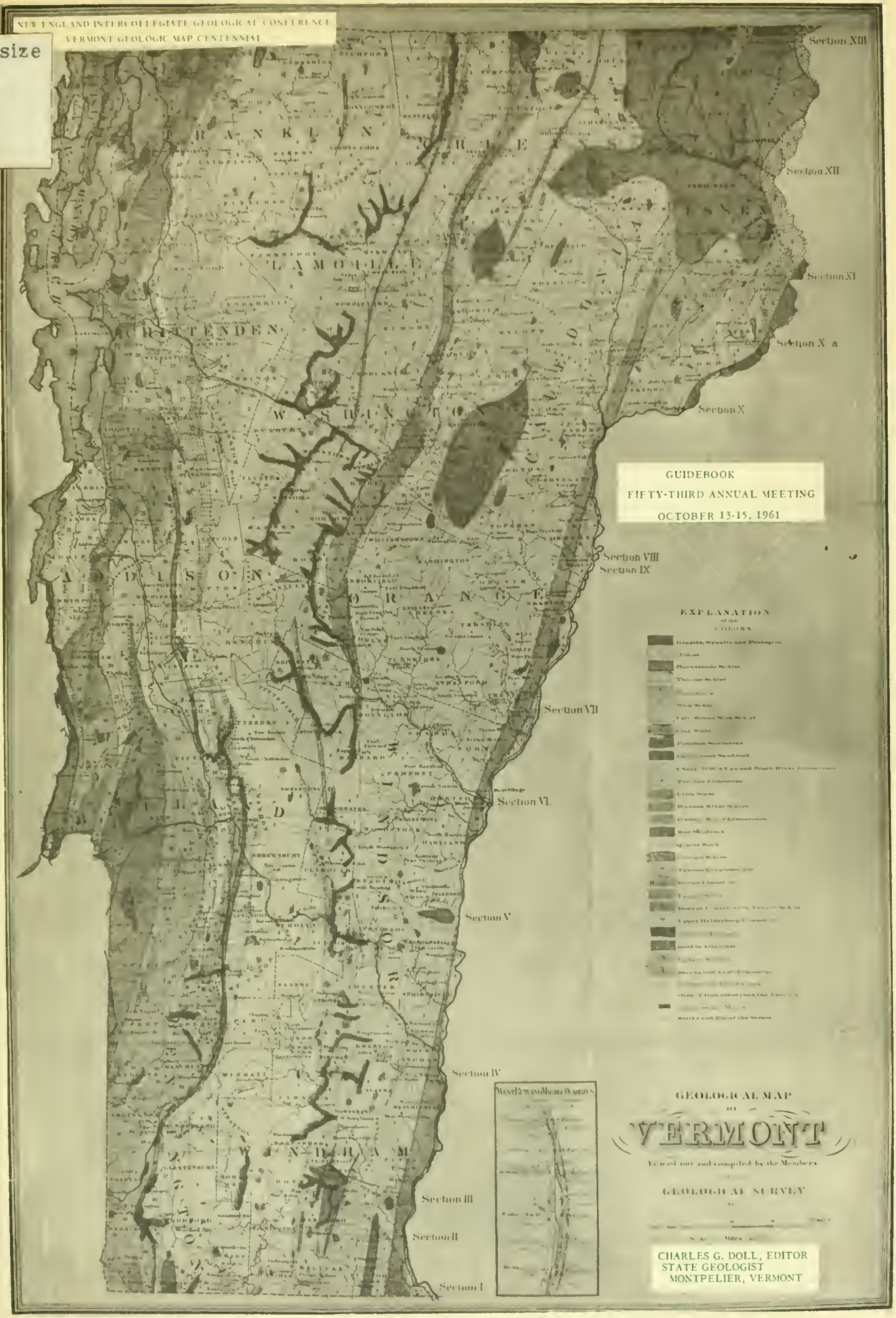
NEW ENGLAND INTERCOLLEGIATE GEOLOGICAL CONFERENCE
VERMONT GEOLOGIC MAP CENTENNIAL



GUIDEBOOK
FIFTY-THIRD ANNUAL MEETING
OCTOBER 13-15, 1961

CHARLES G. DOLL, EDITOR
STATE GEOLOGIST
MONTPELIER, VERMONT

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CONTENTS

FOREWORD

This year, 1961, marks the 100th anniversary of the Edward Hitchcock Geological Map of Vermont. It seems fitting, therefore, to dedicate this Guidebook, which was prepared for the 53rd Annual Meeting of the New England Intercollegiate Geological Conference and Vermont Geological Map Centennial, to the memory of Edward Hitchcock who explored the geology of Vermont with great enthusiasm and, with his associates, produced two quarto volumes comprising 988 pages and entitled, "Report on the Geology of Vermont: Descriptive, Theoretical, Economical, and Scenographical", published in 1861.

Dr.Hitchcock, who at the time of his office as State Geologist of Vermont was President of Amherst College, was one of the eminent geologists of his time, a prolific writer on many diversified subjects, and an expert teacher.

In keeping with the historical significance of this map anniversary the current geologic map has been given the title, "Centennial Geologic Map of Vermont".

This Guidebook contains material which is adapted for use along with the Centennial Geologic Map of Vermont. Most places described therein are easily accessible by automobile and it is hoped will provide enjoyment to those interested in the challenging geology of the state.

ACKNOWLEDGMENTS

The Editor expresses his thanks and appreciation to the field trip leaders for their cooperation in the preparation of this Guidebook. He is pleased also to acknowledge the help of assistants and fellow geologists during the time of the meeting and at other times.

To the Mineral Industries cooperating, and the landowners who readily gave permission to trespass, are extended the gratitude of the Conference.

The State Geologist expresses particular appreciation to his fellow members of the Map Committee, whose names appear on the Centennial Geologic Map of Vermont, for their valuable and expert assistance in the preparation and compilation of this map. They gave freely of their time and were devoted to the project.

Finally, and not the least, the State Geologist recognizes the importance of the contributions made by all geologists associated with the Basic Mapping Program of the Vermont Geological Survey; without their cooperation the new state geologic map would not now be possible. Their contributions are recorded under Primary Information on the map. The stimulating and pleasant associations in the field will be long remembered.

TRIP A-1

Excursion across the Green Mountains
Hinesburg to Montpelier

TRIP A-1

Excursion across Green Mountains - Hinesburg to Montpelier

Assemble in buses on State Street in front of State Capitol, Saturday, October 14, 1961, 8:00 A.M.

Leader: W.M. Cady

INTRODUCTION

This excursion starts near the eastern edge of the miogeosynclinal zone, which is exposed chiefly in the Champlain Valley, and continues eastward into rocks of the eugeosynclinal zone in and east of the Green Mountains. The major structure is the Green Mountain anticlinorium, which trends north in the western part of the eugeosynclinal zone. To the west are the Hinesburg and Middlebury synclinoria, which are in line and are separated by a culmination in Monkton, and to the east is the Connecticut Valley--Gaspe synclinorium. Minor folds trend both parallel to and across the northerly trend of the anticlinoria and synclinoria. The axial surfaces of certain of the minor cross folds in the Green Mountain anticlinorium are parallel to regional foliation, which in most places is parallel to bedding, and which is in turn folded about the axes of minor folds that trend north and are apparently of the same generation as the anticlinorium. Granitic plutons are almost entirely unknown in the northern Green Mountains, which suggests that this region may be an excellent one in which to study the effects of purely dynamo-thermal metamorphism. The route of the excursion appears to coincide with the thickest section of the eugeosynclinal zone in Vermont.

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TRIP A-1

STOP 1. Hinesburg overthrust at Mechanicsville, Burlington quadrangle

0.0 miles — Below the thrust plane are parts 3 and 4 of the Bascom formation (Ob)-a formation of the Lower Ordovician Beekmantown group. Above the thrust plane is the lower part of the Lower Cambrian Cheshire quartzite(Ꞓc). Part 3 of the Bascom is a blue-gray limestone with sandy stripes. Part 4 includes buff dolomite and calcareous phyllite. The Cheshire is here a "dirty" quartzite. Silicified drag folds are noteworthy features of the Cheshire. Please stay out from beneath overhang where large blocks have fallen!

STOP 2. Cambrian(?) "West Sutton" phase of the Fairfield Pond member (Ꞓufp) of the Underhill formation(Ꞓu)

1.2 miles — Reddish, purple, and green phyllite on the west, overturned limb of an anticline facing toward the west. Vein quartz and vein chlorite are common here. This facies extends about half way south through Vermont and has been traced more than 100 miles northeastward in Quebec; though not mappable as a formation it occurs frequently enough to serve as a good guide to the base of the Fairfield Pond member of the Underhill, where the White Brook dolomite(Ꞓuw) is missing.

1.9 miles — In passing note the Pinnacle formation(Ꞓp) north and south of the road and a little west of Rhode Island Corners. The Pinnacle here is on the east topping normal limb of the anticline mentioned at Stop 2.

1.9-3.5 miles — Rhode Island Corners to Fays Corners

Most outcrops seen from road in passing are of Fairfield Pond member of the Underhill formation--schistose quartzite and quartzose schist. Note large beaver pond with beaver house, on left.

STOP 3. Fays Corners, Cambrian(?) Pinnacle formation

3.5 miles — Graywacke with a few carbonate interbeds. The graywacke is typically "pinstriped." Shows folds well.

7.7 miles — In passing note Pinnacle just beyond Y in road. Enter Camels Hump quadrangle. In Richmond village is the Round Church. Foundation is painted red (it isn't the Monkton quartzite!). The church steps are of *Maclurites magnus* bearing Chazy limestone. Church has 16 sides. Rock for about a mile east of Richmond is Underhill; Pinnacle follows.

STOP 4. Jonesville, Cambrian(?)Pinnacle formation

11.7 miles — Excellent exposures of nearly vertical Pinnacle. Shows structural tops both to east and west, but the most satisfactory evidence shows tops to west.

Note dendritic pattern on smooth glaciated surfaces produced by humic(?)acid solution along roots of trees now removed.

STOP 5. Cambrian(?)Underhill formation at the axis of the Green Mountain anticlinorium. Rock, which varies from schist to gneiss, contains boudinaged quartzite beds. Exposure contains chiefly north trending folds, the axial planes of which dip east. Schist beds contain garnet, gneiss beds contain biotite.

16.2 miles

17.1 miles Note east-dipping Underhill, in passing.

18.5 miles In passing, note carbonaceous schist of the Hazens Notch formation (Ꞓh). Hazens Notch is a large west-pointing tongue of interbedded carbonaceous and noncarbonaceous quartz-sericite-chlorite-albite schist. Interesting features of some of the noncarbonaceous rocks are porphyroblasts of black albite--black owing to finely disseminated carbon. Apparently it is all the carbon left in schist that originally contained much more.

STOP 6. West edge of Waterbury, Cambrian(?)-Lower Cambrian Hazens Notch formation

21.6 miles

Contains a large amount of very quartzose noncarbonaceous schist that is like, and in about the same stratigraphic position as, the Pinney Hollow formation(Ꞓph), which appears in mapping width a few miles south, between the Hazens Notch and Ottauquechee formations(Ꞓo).

Various styles of folds plunge steeply east down dip. North trending folds are hard to find. Common are rather tight folds in quartzite beds and folds in slip cleavage layers.

STOP 7. Waterbury interchange, Middle or Upper Cambrian Ottauquechee formation(Ꞓo)

22.4 miles

STAY NEXT TO ROAD CUT AND OFF OF TRAVELED ROADWAYS!

Extensive exposures, typically of carbonaceous phyllite and carbonaceous quartzite; noncarbonaceous phyllite becomes more abundant toward the west in the transition downward into the Hazens Notch formation. Folds trend both north parallel to the axis of the Green Mountain anticlinorium and eastward down-dip. Moreover, folds with intermediate orientations are found.

The variously oriented folds point up the existence of many problems, which appear to be increased here because the style of folding seems to be unrelated to orientation. Near the axis of the anticlinorium on the other hand, notably on the summit of Mt.Mansfield, northeast trending quartz rods and flow folds are flexed over 'brittley' chevron folds.

WALK TO STOP 8 GUIDED BY STATE POLICE! Enter Montpelier quadrangle.

STOP 8. Waterbury village, copper vein in Ottauquechee formation

23.2 miles

Chalcopyrite between greenstone to west and carbonaceous phyllite to east, in road cut. Was not known until road cut recently opened. Greenstones or amphibolites are common associates of the few copper deposits known in the belt of the Ottauquechee and overlying the Stowe formation(OꞒs), on the east flank of the Green Mountain anticlinorium.

East of Stop 8 (location of Interstate Route 89 not shown on Montpelier quadrangle) are various greenstones interbedded in the quartz-sericite-chlorite schist of the Stowe formation.

STOP 9. Mad River, Ordovician-Cambrian Stowe formation(O€s)

30.0 miles — Large exposures of the Stowe formation show chiefly granular white quartz segregations in the quartz-sericite-chlorite schist. In places segregation has not taken place and relics of buff to green quartzite beds are preserved. The principal foliation is slip-cleavage schistosity as opposed to the bedding schistosity seen in many other formations.

STOP 10. Middlesex Gorge, Middle Ordovician Moretown member of the Missisquoi formation(Omm)

30.8 miles

Excellent exposures of the Moretown "pinstripe", so named by J.B. Thompson, Jr. and John Rosenfeld in southern Vermont. Speculation is invited as to the origin of the foliation, which partly for convenience has been designated bedding foliation. That it is bedding foliation at many localities is shown by its parallelism with quartzite beds.

Fold layers transect the bedding foliation. In the belt near the base of the Moretown most folds in these layers are dextral. Look for a few places where dextral and sinistral fold layers form a cross. The axes of these folds all plunge very steeply and vary in plunge direction through the vertical.

The "pinstripe" is produced by alternating granular and micaceous layers, the latter paper thin. The granular layers contain quartz, lesser albite and chlorite, the micaceous layers sericite and some epidote or calcite. "Pinstripe" is locally an axial-plane feature in the Moretown, but not in these exposures.

STOP 11. West edge of Montpelier, Middle Ordovician Moretown member of the Missisquoi formation

37.0 miles

DO NOT CROSS INTERSTATE!

Contains both pre- and post-metamorphic mafic dikes. The pre-metamorphic(greenstone) dikes are commonly parallel to axial plane cleavage of folds, more prominent near the top of the Moretown than near the base. Individual fold layers are less abundant than systems of larger folds with varied orientation: The "pinstripes" are farther apart than at Stop 10.

The post-metamorphic dikes are spessartites, camptonites, or simply basalt, probably related to the White Mountain and Monteregian plutonic series.

38.9 miles — Pavilion Hotel, Montpelier

At your convenience go up back of the east wing of the State House (gold dome) and see the Lower(?)Silurian Shaw Mountain formation(Ss), succeeded eastward by the Devonian-Silurian Northfield slate (DSn). The lowest (western) part of the Shaw Mountain here is a pale chlorite schist; vesicles or amygdules indicate a lava flow. The bulk of the Shaw Mountain back of the State House is ferruginous(ankeritic)sericitic quartzite.

The Northfield slate is succeeded eastward in the city of Montpelier by the Devonian Waits River crystalline limestones and phyllites(Dw).

TRIP A-2

Barre to Strafford via Bradford

Barre to Strafford via Bradford. Lithology of the rocks between the Shaw Mountain belt and the Monroe line. Monroe fault, development of cleavages on east side of Strafford arch, and structure of Strafford Village area.

East-central Vermont

Between the Northfield slate at Montpelier and the Monroe fault at Bradford, there are four persistent lithologic belts. If these are numbered from west to east, the first and third belts consist of alternations of calcareous and argillaceous beds, and the second and fourth belts consist of alternations of schist and micaceous quartzite beds. Doll (1951) has named the first belt the Barton River formation(Dwb) and the second the Westmore formation. He (Doll, 1944) also named the fourth belt the Gile Mountain formation(Dg). Another name, the Waits River formation(Dw), has been used for the first and third belts collectively (White and Jahns, 1950) on the assumption that the third belt is primarily a structural repetition of the first.

The rocks of these belts overlie the Shaw Mountain formation(Ss) to the west, and are generally considered to be Silurian and/or Devonian in age. They are bordered on the east by the pre-Silurian Albee(Oal) and Ammonoosuc(Oa) formations. The Albee formation is very similar lithologically to the Moretown formation(Omm), and is very probably correlative. Very broadly, therefore, the four belts referred to above collectively represent a wide belt of younger rocks bounded on either side by older rocks. Cady (1960) has referred to this whole wide belt as a synclinorium because of this general relationship.

The first individual belt (Barton River formation) and at least part of the second (Westmore formation) appear to overlie the older rocks to the west in an orderly continuous ascending sequence. The major problem of the geology of east-central Vermont has to do with the nature of the eastern boundary of the fourth belt (Gile Mountain formation) and with the internal structure and order of superposition within the third and fourth belts.

The eastern boundary of the fourth belt transects the bedding of the older rocks to the east on both a regional and local (STOP 4) scale, and has been called a fault, the Monroe fault. Inasmuch as it is principally the older rocks that are truncated, the relationships could be explained by assuming that the boundary is an uncomformity -- the pre-Silurian uncomformity exposed elsewhere in New England -- or possibly an unconformity modified by faulting, so some have preferred to call this boundary the Monroe "line." If the rocks of the fourth belt (Gile Mountain formation) are younger than the calcareous rocks of the third belt, the Monroe "line" obviously must be a fault. If, however, the internal structure of belts 1 to 4 is grossly synclinal, and the rocks of belt four are older than those of belt three, the Monroe "line" may simply be an unconformity.

The order of superposition in belts 3 and 4 is not easy to determine because the original structure, whether synclinal or otherwise, has been obscured by a late-stage deformation that produced, primarily in belt 3, a group of recumbent folds and a tremendous arch in the cleavage and axial planes of these recumbent folds. This cleavage arch can be traced as a continuous arch or

series of en echelon domes for most of the length of Vermont.

The most likely hypotheses for the structure of belts 1 to 4 are the following:

1) Belt 1 is the same as Belt 3, and Belt 2 is the same as Belt 4. The repetition is due either to coincidence of Belt 2 with a syncline and Belt 3 with an anticline (Dennis, 1956), or to faulting. (Fig. 1A) Correlation of the rocks of belts 2 and 4 is made likely by their apparent connection around the north-plunging nose of the cleavage arch in the Island Pond quadrangle.

2) Belts 2 and 4 are the same, and are connected in depth to form a syncline (Fig. 1B). The rocks of Belt 3 are younger. The rocks of Belt 1 are either older than those of belts 2 and 4, or grade eastward, by change of facies, into those of Belt 4. This hypothesis is difficult to reconcile structurally with the apparent connection of belts 2 and 4 in the Island Pond quadrangle.

3) The sequence is essentially homoclinal from west to east, with Belt 1 the oldest and Belt 4 the youngest. Northward disappearance of the calcareous facies of Belt 3 might explain the apparent junction of belts 2 and 4.

There is, as yet, no certain basis for choice among these hypotheses. The field excursion will be concerned with three main topics: (1) evidence for local truncation along the Monroe fault (or line); (2) evolution of the later-stage structural features (cleavage and minor folds) that obscure the primary structure, and (3), in extension of (2), the recumbent folds with cores of Gile Mountain formation that extend across the cleavage arch in the Strafford village area.

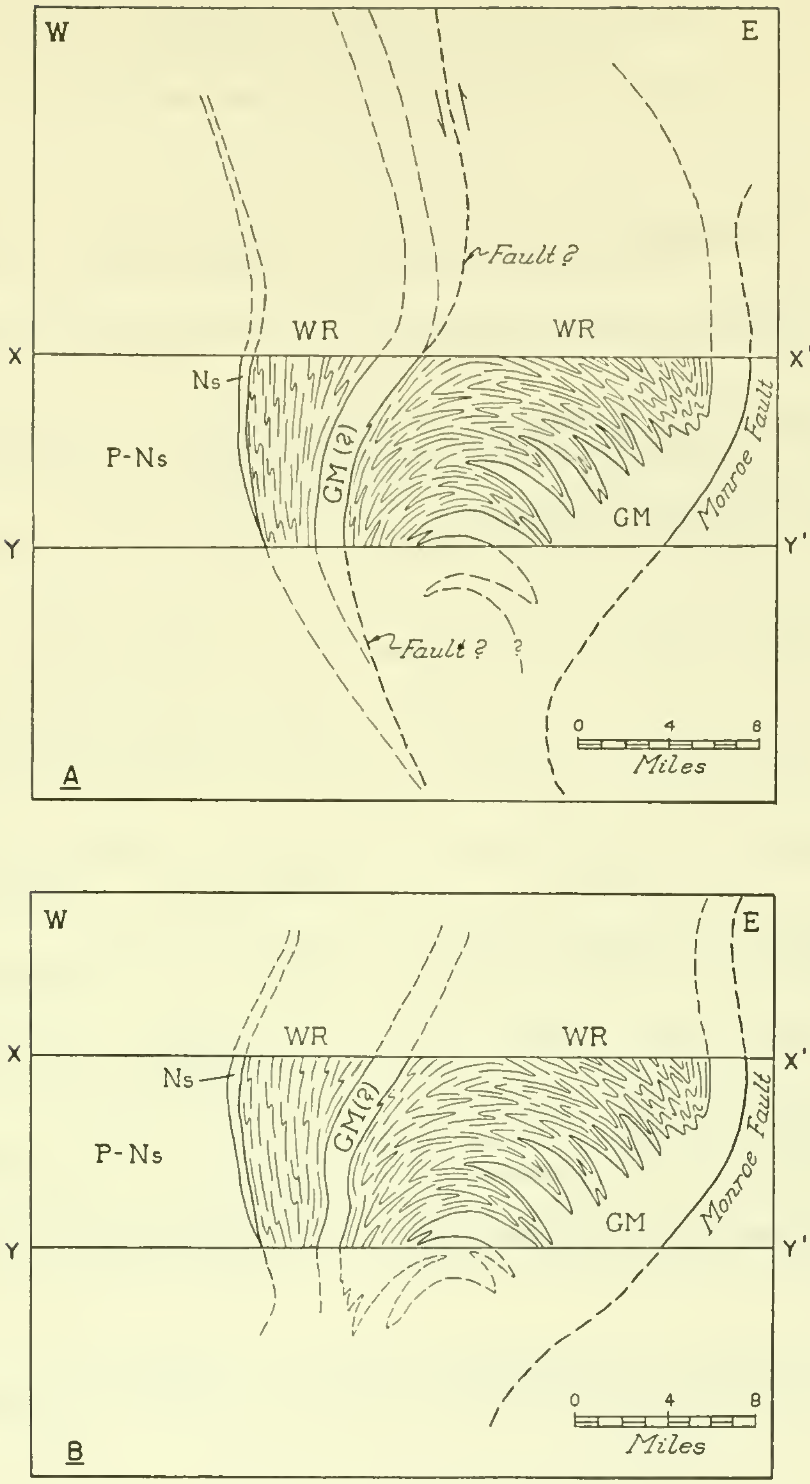

FIG. 12.—(Legend on facing page)

FIG. 12.—Diagrammatic east-west structure sections of central and east-central Vermont, showing two possible interpretations of surface relations. Data projected from map (fig. 2) onto planes of sections, with northward-plunging axes of minor folds as projection lines. Details along lines *X–X′* represent structure exposed in northern part of Barre, East Barre, and Woodsville quadrangles; details along lines *Y–Y′* represent structure at surface at approximate latitude of Bethel and South Strafford. Meetinghouse slate, next to Monroe fault, omitted from diagram. *P–Ns*, rocks older than Northfield slate; *Ns*, Northfield slate; *WR*, Waits River formation; *GM*, Gile Mountain formation; *GM(?)*, rocks provisionally assigned to Gile Mountain formation.

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east-central Vermont and related problems

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TRIP A-2

Sunday, October 15, 1961, 8:00 A.M. Excursion across east-central Vermont, Barre to Strafford via Bradford.

Leaders: Walter S. White and Charles G. Doll

MILES

0.0 Begin mileage at common in center of Barre, at intersection of Rtes. US 302 and Vt. 14.

Proceed south on Vt. 14 (S. Main St.)

0.9 Turn left, following signs to Websterville.

2.4 Turn left at crossroads by cemetery.

3.7 STOP I - Wells Lamson granite quarry, Websterville

One of the five principal quarries in the Barre "granite", which is primarily used for monumental stone. The rock is an even-grained quartzose granodiorite with biotite as the dark mineral. Differences in color and texture are accentuated by polishing to yield a considerable variety in the finished products.

This pluton is about 4 miles long and 2 miles wide; it intrudes the Westmore formation (= Gile Mountain formation) and the western border of the calcareous Waits River formation. A septum of the Westmore formation almost divides the pluton into two parallel plutons; the margin of this septum can be seen in the east wall of the quarry. Although the contact relations cannot be satisfactorily studied from the quarry rim, it may be remarked that visible contacts are typically parallel to the bedding and a schisosity of the wall rocks, but the cross-cutting relationships are also common. Most contacts are extremely sharp. Both the layering and the long axes of inclusions in the "granite" are more or less randomly oriented. The "granite" post-dates practically all of the deformation of the country rock, and has made way for itself by a combination of stopping and bulging of the country rock.

Bear left at fork just beyond quarry.

4.8 Turn left past stores, and proceed 0.2 miles to highway intersection. Turn right on US 302 (Vt. 25), and follow signs to Bradford. The road for the next 7 miles passes through an area of heavy drift cover, and poor exposure. The hills on the left are underlain by Knox Mtn. granite(nhu).

10.9 Outcrops of Knox Mountain granite on left.

12.1 Bear right on Vt. rte. 25, toward Bradford.

14.1 West Topsham village.

17.8 Waits River village. The rounded grassy tops and very steep lower slopes of the hills here and for the next five miles are typical of the terrain underlain by the Waits River formation. Note the typical dark-brown, rough weathered surface of outcrops of these calcareous rocks.

24.1 Bridge over Waits River. The rocks here and beyond are interbedded schists and micaceous quartzites of the Gile Mountain formation, highly crumpled, for the most part.

25.0 and 25.5 Granite dikes more or less parallel to slip cleavage (later cleavage) in crumpled schists on left.

26.2 to 26.6 STOP II - Bradford Center village

Outcrops of crumpled schist and micaceous quartzite typical of Gile Mountain formation, at both ends of the village. Slip cleavage more or less parallel to the axial planes of the folds is well developed in some parts of the outcrops and poor in others. It tends to be better developed in the schist than in the more quartzose layers. Bedding and an earlier schistosity are crumpled and cut by this slip cleavage. Though the intensity of the later crumpling here tends to obscure the relationship between the earlier schistosity and the bedding, painstaking attempts to follow the trace of individual schistosity surfaces will commonly show that the schistosity and bedding are not strictly parallel. It may, in fact, be difficult to follow individual lithologic boundaries for more than a few feet, which suggests that the rocks were already sheared and folded before being further crumpled and cut by slip cleavage.

A thin granite dike is more or less parallel to the axial plane of the later folds in the outcrop at the southeast end of the village. The dike is later than and unaffected by the folding of the later stage.

28.7 STOP III - Gile Mountain formation with impure carbonate layers.

Rocks are less metamorphosed than those at STOP II. The schistosity and bedding generally strike about N. 20° E., and dip 50-55° S.E. Some tight folds in calcareous layers (best seen on the upper surface of the roadcut) seem to have axial planes parallel to the schistosity, and would thus be classed as folds of the earlier stage (An element of uncertainty exists because the style of folding in the carbonate rocks is commonly different from that in the non-calcareous rocks). Slip cleavage striking about N. 25° W. and dipping 35° N.E. is moderately well developed in some of the more crumpled parts of the exposures, and only incipient in other places.

29.1 At fork in highway, bear right on Route 25A

30.2 Turn right (south) on U.S. Route 5, and proceed 0.3 miles to paved farm road on right.

30.4 STOP IV - Monroe fault at Bradford Lower Plain

Outcrops are 500-1000 feet west of US Rte. 5, and north of the farm road. From east to west, the rocks in this group of outcrops are (1) chlorite schist -- the Sunday Mountain volcanics(Oa) of Hadley, (possibly = Ammonoosuc volcanics); (2) greenish-gray chlorite-sericite schist with thin interbeds of quartzite -- the Albee formation; and (3) dark-gray slaty schist with micaceous quartzite interbeds -- the Meetinghouse member(Dgm) of the Gile Mountain formation. The boundary between (2) and (3) strikes nearly north-south, and is strongly discordant with respect to the northeast-striking schistosity in the rocks on either side; the trend of bedding on both sides is not readily determined, but it, too, seems to be truncated by the boundary.

Some minor folds with sinistral pattern in plan, and northeast-striking slip cleavage parallel to their axial planes, occur locally in the Meetinghouse member. Folds with this pattern and orientation are common in the vicinity of the Monroe fault for 10 miles or so north of here; their orientation and pattern differ notably from those of the later folds formed farther west (e.g. at STOPS II and III).

From STOP IV, retrace route for 1.4 miles.

30.8 At 0.3 miles north of STOP IV, turn left onto Rte. 25A.

31.9 Bear left on Route 25.

32.0 Leave Route 25, and bear left on Rowell Brook Road.

33.2 Go straight at cross roads.

34.2 Go straight at cross roads.

35.1 Bear left on gravel road.

38.3 STOP V - West Fairlee Center, roadcut 0.3 miles northeast of church.

Gile Mountain formation, mainly dark-gray mica schist in this exposure. The slip-cleavage is still clearly recognizable as such in this outcrop, particularly if one examines it with a hand lens: though the cleavage planes are very closely spaced in most of the rock here, the earlier schistosity is still visible in the plates between slip-cleavage surfaces. Farther west the spacing becomes still closer, and it becomes more and more difficult to find remnants of the earlier schistosity that are not smeared into parallelism with the slip-cleavage.

38.6 Church on right.

42.7 Turn right at intersection on north side of Lake Fairlee.

43.2 Bear right, away from lake, at fork.

44.6 Turn right (north) on Rte. 113 at intersection.

45.6 West Fairlee. Turn left at general store.

47.1 Dumps and slag piles of old Ely (Copperfield) copper mine.
The mine, whose main opening is 0.7 mi. north of the road, was last operated in 1905. During the '50's, considerable copper was reclaimed from the dumps by the operators of the Elizabeth mine at Strafford.

47.7 Bear left at fork.

48.6 STOP VI - Gile Mountain formation

Outcrops in pasture on right are predominantly micaceous quartzite, with subordinate mica schist and kyanite mica schist. The schistosity here has the same general attitude as the slip-cleavage at STOP V, and is believed to represent the end-product of intense development of slip-cleavage. The schistosity is parallel to the axial planes of minor folds; these folds are predominantly dextral in pattern, reflecting their position on the southwest flank of a major fold that opens to the southeast.

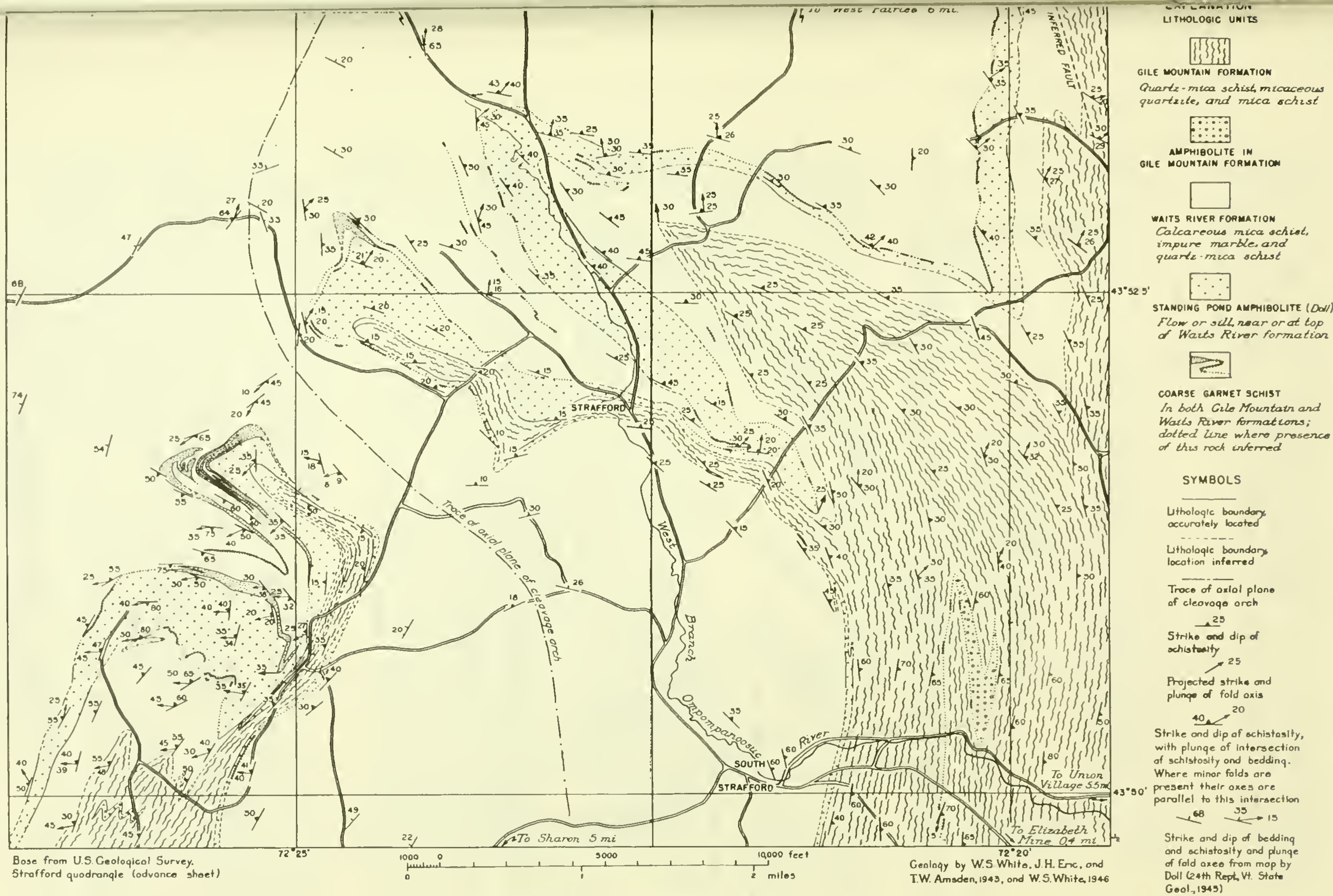

FIG. 9.—Geologic map of the Strafford Village area, Vermont

Courtesy Journal of Geology
The University of Chicago Press, Publisher

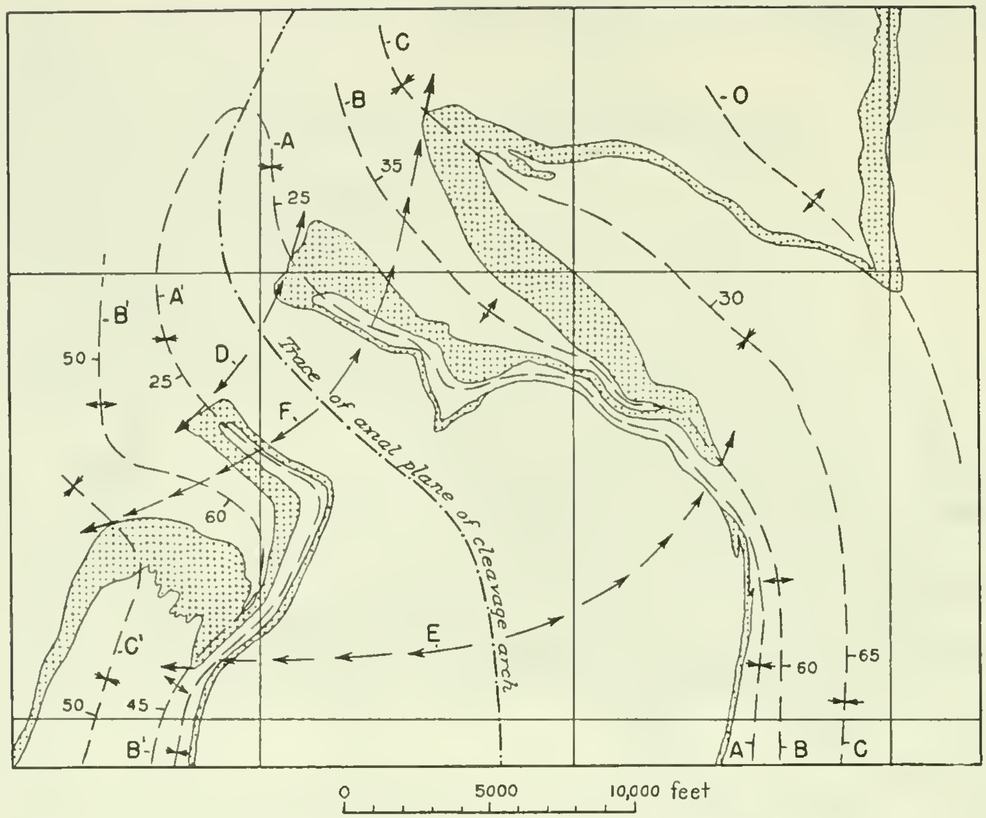

FIG. 10.—Tectonic map of the Strafford Village area (see fig. 9). Folds are shown by distribution of Standing Pond amphibolite of Doll (*stippled*). *A*, *A'*, *B*, *B'*, *C*, *C'*, and *O* are traces of axial planes of folds, with dips also indicated; and *D*, *E*, and *F* are horizontal projections of fold axes. *A*, *A'*, *D*, Strafford Village syncline; *B*, *B'*, *E*, Grannyhand anticline; *C*, *C'*, *F*, Old City syncline; *O*, Orange anticline.

(The plunge of the folds is more or less down the dip of their axial planes, so one cannot speak of "anticlines" and "synclines" in their conventional senses.) At STOP VII we shall cross the core of another such major fold whose axial plane has been bowed upward in the Strafford cleavage dome.

49.5 Turn left at intersection.

50.2 Cross over top of ridge. Here and for the next three miles beyond, road is in an area of the calcareous Waits River formation.

54.3 Turn left on paved road at intersection.

55.0 Keep left (straight ahead) at Strafford common.

55.2 Home of Justin Morrill, founder of Land-Grant College movement, on left.

STOP VII - Grannyhand Hill. Major recumbent fold in boundary between Waits River and Gile Mountain formations (See figures 2 and 3).

Route to be followed on foot goes up side road to left (northeast) approximately 1.0 mile, then about 0.3 mile down across brook in pasture and up to top of ridge to northwest, and then south across the outcrops along the ridge crest back to origin. On the way up the road, between 4000 and 5000 feet, route crosses Standing Pond amphibolite(Dws).

Going south along the ridge top, one crosses the following sequence of lithologic units.

(1) Waits River formation. Farther south, the Standing Pond amphibolite separates calcareous rocks of the Waits River formation on the west from non-calcareous rocks of the Gile Mountain formation on the east. In this vicinity, a thin band of calcareous rock appears between the Standing Pond amphibolite and the Gile Mountain formation, and this band increases in width towards the north. The outcrops here belong to this band, whose breadth here is about 500 feet.

(2) Standing Pond amphibolite, band about 700 feet wide. There are no criteria here to demonstrate whether this rock is intrusive or extrusive, but pillow structures have been observed in it in other quadrangles.

(3) A few feet of mica schist with large garnets (up to two inches in some outcrops), typical of the contact zones of the amphibolite.

(4) Waits River formation in the core of a fold that opens westward. This is the same fold that was crossed on the road; the calcareous rocks and the coarse garnet schist wrap around the nose a few hundred feet to the east.

(5) Coarse-garnet schist.

(6) Standing Pond amphibolite.

(7) If the calcareous rocks of (1) are present on this limb of the fold, they would reappear here, but outcrops are poor and they have not been found.

(8) Gile Mountain formation. Belt about 500 feet wide representing the highly attenuated core of a fold that opens eastward. The belt maintains this width for a distance of three miles.

(9) Standing Pond amphibolite. An outcrop representing about 10 feet of thickness appears to be all that remains of a unit that is normally about 300 feet thick. The regional map pattern suggests that this small thickness is due to tectonic thinning rather than original differences of thickness.

(10) Waits River formation. This body of the calcareous rocks underlies the whole core of the Strafford cleavage dome.

58.7 Turn left, following main road at fork in road at far end of South Strafford village.

61.5 Keep straight on main road at Campbell Corner

63.0 STOP VIII - Rices Mills

Gile Mountain formation, with later folds plunging gently to both north and south.

Large outcrops along both sides of stream to right (southwest) of road. The average attitude of the fold axes is nearly horizontal, as it is in the central part of the Strafford cleavage dome due west of here. The dominant, but not sole pattern of the minor folds suggests relative rise of the rocks on the east with respect to those on the west. This is the characteristic pattern of the later folds on the east side of the cleavage arch.

69.4 Junction of Strafford road with U.S. Rte. 5 at Pompanoosuc.

TRIP B-1

Economic Geology of the Belvidere Mountain Asbestos Area, Vermont Asbestos Mines Division of the Ruberoid Company

Economic Geology of the
Belvidere Mountain Asbestos Area,
Vermont Asbestos Mines
Division of the Ruberoid Company

INTRODUCTION

General Features

The rocks of the Belvidere Mountain area comprise schist, greenstone and amphibolite, and various ultramafic igneous rocks and their alteration products. The rocks are in the east limb of the Green Mountain anticlinorium. A broad open fold -- with a dextral pattern, a wave length of more than a mile, and a moderate southerly plunge -- is a prominent local structural feature in which the body of ultramafic rock is situated; layering in the ultramafic rocks partakes of the folding. This fold is of the style of the Green Mountain anticlinorium. Locally, east-trending folds that are folded by the Green Mountain folds can be observed in outcrop, and the southeast-trending fold between the Lowell quarry area and the Eden quarry area probably is related to these earlier folds.

The ultramafic rocks form a lenticular body more than 1,000 feet thick and probably more than 2 miles in longest dimension. The ultramafic and derived rocks consist of dunite, serpentinite, talc-carbonate rock, carbonate rock, and steatite (talc rock). Serpentinite occurs both as massive rock with the textural appearance of dunite -- with which it shows all gradations -- and as highly sheared rock with a very irregular schistosity. Commonly the sheared serpentinite is near the border of the body, the dunite and massive serpentinite generally near the center. Talc-carbonate rock and carbonate rock are irregularly distributed, in places apparently along faults and joints.

The contacts of the ultramafic body display a variety of relations. In the Lowell quarry body, the serpentinite of igneous parentage is bordered by a thin (6 inches or less) zone of replacement serpentinite, consisting of chlorite and antigorite, derived from schist. The replacement serpentinite grades very abruptly and irregularly into lime silicate rock consisting of diopside, vesuvianite, clinozoisite, garnet, and (locally) prehnite, as much as 3 feet thick. Smaller ultramafic bodies consist of a core of serpentinite surrounded by shells of talc-carbonate rock and steatite, and a thin rim of blackwall chlorite rock altered from the bordering schist. In some places, steatite at the margins of the ultramafic body is bordered by a tremolite rock zone several feet thick.

Chrysotile asbestos occurs in two principal habits -- as cross-fiber veins in dunite and massive serpentinite, and as slip-fiber asbestos in highly sheared serpentinite. Though some of the cross-fiber veins are long and of excellent quality, and consequently more spectacular in appearance than the slip-fiber asbestos, cross-fiber asbestos is relatively minor in quantity. Slip-fiber asbestos, from the highly sheared serpentinite, constitutes the greater part of the deposit.

ECONOMIC GEOLOGY of the Belvidere Mountain asbestos area, Vermont Asbestos Mines, Division of the Ruberoid Company.

Leave Montpelier in private cars on October 14, 1961, at 8:30 A.M. Arrive at the asbestos quarry 10:00 A.M.

Leader: A.H. Chidester

Participating at the mine: I.E. Matthews, Superintendent and D.R.Nichols, Geologist.

STOP 1. 1400-foot level, NE side of quarry. General view of the area.

Discussion of the structural and stratigraphic setting of the locality, and of the distribution and structural relations of the ultramafic rocks. See geologic map and structure section. Examine contact features of the Lowell quarry body and of small satellite bodies along the northeast side of the Lowell quarry. In the Lowell quarry body, serpentinite derived from dunite is bordered by a thin shell of replacement serpentinite (antigorite-chlorite rock) and a shell of variable thickness of lime silicate rock (diopside-clinozoisite-garnet-vesuvianite). In the small satellite bodies, a central core of serpentinite is bordered by successive shells of talc-carbonate rock, steatite, and blackwall chlorite rock.

Walk to 1300-foot level; on way examine structural features and facies relations in the country rock. In 1300-foot level see working faces of highly sheared serpentinite asbestos ore.

STOP 2. 1115-foot level. Cross-section of ore body, exposing massive dunite, sheared serpentinite ore, and a thin septum of coarse amphibolite altered to lime silicate rock.

STOP 3. 1050-foot level. Contact relations and wall rock alteration (replacement serpentinite, lime silicate rock) between serpentinite and amphibolite.

STOP 4. (If time permits.) Collecting of vesuvianite and diopside in recently exposed septum of lime silicate rock.

LUNCH. After lunch, personnel of the Ruberoid Company will describe mining and milling practices, and conduct the group on a brief tour through the mill.

STOP 5. 1400-foot level, SW side of quarry. A small fault is exposed along the southwest side of the narrow syncline of amphibolite. A ramp to the 1400-foot level exposes amphibolite along the southwest wall of the Lowell quarry, and a septum of amphibolite and lime silicate rock within sheared serpentinite in the Lowell quarry body.

STOP 6. C-area. Layering in dunite, shear zones, and asbestos veins are well exposed in the ultramafic body. Lime silicate and replacement serpentinite in amphibolite at the margins of the serpentinite body are well exposed. At several places along the contact there are irregular veins of coarse aggregates of calcite, magnetite, and large clear green books of chlorite.

RETURN to Montpelier by way of Smugglers Notch and Mount Mansfield.

TRIP B-2

The Barre Granite Quarries

TRIP B-2

The Barre Granite Quarries

Leader: Brewster Baldwin

Participating at the quarries:

R.H. Smith, Dir. Public Relations
C.Y. Ferris, Chief Engineer

ROAD LOG

Route from Montpelier to Graniteville, via U.S. 2, U.S. 302, Vermont 14, and Quarry Hill Road; 11.1 miles.

Assemble in parking lot behind State Office Buildings. The organized tour of the quarries and manufacturing plant will probably end at about 1 p.m.; bring a lunch if you wish to linger for more samples or photographs.

Leave at 8:30 a.m., Sunday, October 15. Turn right onto State Street and continue to end; turn right at traffic light onto Main Street; cross bridge over Winooski River; turn left at traffic light onto U.S. 2 at Mobilgas station.

0.0 Traffic light at intersection of U.S. 2 and Main Street.

1.7 Junction, KEEP RIGHT onto U.S. 302; U.S. 2 continues straight.

2.9 Howard Johnson's on left.

3.1 Shopping center on left.

5.3 Guardian Memorials on right.

5.6 Speed limit 25 mph.

6.5 Shopping district of Barre; Paramount Theater on left.

6.7 BEAR RIGHT at city park. CONTINUE STRAIGHT onto Vt. 14; U.S. 302 goes off to the left toward East Barre.

7.2 Stone bridge. On right, plant of Rock of Ages Capacitors, Inc., which began operations in World War II. Continue up hill. BE PREPARED FOR TURN TO LEFT.

7.6 TURN LEFT at sign "Famous Barre Granite Quarries, 3 miles"; continue past Lawson Granite Company up Quarry Hill Road.

8.4 Road bends to left near top of hill, and crosses railroad tracks. Scenic view to northwest.

9.0 Cemetery on left; continue straight across road intersection. Road to left goes to Wells-Lamson quarry in Websterville. From here on, route is shown in Figure 1.

10.1 Road intersection; continue straight. Craftsman Center on left, where granite monuments are finished.

10.2 Picnic area on right.

10.4 TURN LEFT onto main street of Lower Graniteville.

11.0 Saw Plant on left.

11.1 Park on right, near Compressor Building. Go to observation point, beyond locomotive.

The tour will visit the observation point, the xenoliths, and the dike at the Rock of Ages quarry; the contact at the Smith quarry, where the sheeting can be photographed; the saw plant; the manufacturing plant (Craftsman Center); and the locality marked "samples" south of the Smith quarry (good picture point). If time permits, the jointing in the Pirie quarry, and the Wells-Lamson quarry.

GEOLOGY

Regional Setting and Age

The Barre granite is one of many bodies of granite rock in New England. In Vermont, almost all of these bodies lie in rocks of post-Ordovician age, some distance east of the Green Mountain axis. The country rocks represent the metamorphosed complex of detrital sediments and volcanic materials; they form a homoclinal sequence with the younger deposits to the east. It is perhaps significant that the granitic bodies lie in these younger rocks, where geosynclinal subsidence was great.

The Barre granite lies in the Gile Mountain formation (the Westmore formation of Murthy, 1957), a series of mica schists and micaceous quartzites of Devonian age; it abuts on its east side the Waits River formation, which differs from the Gile Mountain formation in containing calcareous beds. A Rb/Sr age determination gives 330 ± 25 million years for biotite in the Barre granite (Murthy, 1957, p. 95). According to Kulp (1961), 330 million years ago was in the Mississippian period.

Limits of the Barre Granite

As is shown in the inset map of Figure 1, the Barre granite extends north-northeast for 4 miles and is 2 miles wide, with its eastern edge at East Barre. Another granite body -- the Knox Mountain granite -- lies several miles northeast of East Barre. The Barre granite crops out on Cobble Hill and on Millstone Hill, which are separated by the northwest-draining valley of Jail Branch. The limits of the granite are tentative. Balk (1927, pl. 2) mapped a number of separate granite bodies, somewhat elongate to the north-northeast, with country rock intervening. More recently, White (1946, fig. 1) interpreted the granite to be one body, separated by tongues of country rock. The limits shown on the inset map are modified from Murthy (1957, pl. 1). The contact of the granite and country rock is exposed in the Wells-Lamson quarry and in the upper Smith quarry (Fig. 1); it is also exposed along the road from Graniteville to Websterville. The granite is generally concordant with the bedding planes of the country rock but locally is discordant.

A dike with chilled contacts cuts the granite on the road just east of the Guide Office. Murthy (1957, p. 97) found it to contain oligoclase-andesine augite, dark green hornblende, biotite, and magnetite; considerable epidote and chlorite are present. He names it a lamprophyre of kersantite-spessartite composition. The dike, or an offshoot, is visible from the observation point, on the quarry wall.

Rock Type

The Barre granite is a medium-textured gray two-feldspar, two-mica granodiorite. The feldspars are oligoclase and microcline, with some altered orthoclase. Murthy (1957) describes and discusses the fact that most of the muscovite occurs as replacement of plagioclase. The amount of biotite controls the shade of gray of the granite. In general, the darker the rock, the greater is its value for monumental stone. Balk (1927) has described several places where two comagmatic varieties occur, and in each case the darker variety is the older; the two varieties can be seen on the "island" in the Rock of Ages quarry where xenoliths are noted (Fig. 1). On this same island, several textural varieties can be seen: a fine-textured granite next to a xenolith; pegmatitic lenses and patches; and slightly porphyritic areas. Even these variations are scarce, and the texture is strikingly uniform.

The mineralogic composition is also strikingly uniform, as demonstrated by Chayes (1952) and Murthy (1957) who both made modal analyses of samples collected to test the range of variation in the granite. Means of their analyses are:

	Chayes	Murthy
number of analyses	21	9
quartz	27.2	24.3
potash feldspar	19.4	20.1
plagioclase	35.2	34.7
biotite	8.1	9.8
muscovite	8.3	9.8
accessories	1.0	1.8

Dale (1923) quotes two chemical analyses of the dark Barre granite. That by Day (1898, p. 224) is for a sample from the Wells-Lamson quarry, and the analysis by Finlay (1902, p. 55-56) is for a sample collected "south of Millstone Hill."

	Day	Finlay
SiO_2	69.56	69.89
Al_2O_3	15.38	15.08
Fe_2O_3	2.65	1.04
FeO	-----	1.46
MgO	tr.	0.66
CaO	1.76	2.07
Na_2O	5.38	4.73
K_2O	4.31	4.29
H_2O	1.02	0.54
P_2O_5	----	tr.
	100.6	99.76

Structure

Although the Barre granite is remarkably homogeneous, it does contain some recognizable internal structures. The most conspicuous are several sets of joints, which are somewhat variable across Millstone Hill. Longitudinal joints trend northeast and dip steeply eastward; those in the Rock of Ages quarry are nearly vertical, whereas those in the Pirie quarry dip about 45 degrees. Cross joints, oriented normal to mineral lineation, strike west to northwest; Murthy (1957) states that they are not everywhere well developed. Sheeting, probably related to the present land surface, is approximately horizontal. In the Pirie quarry it dips fairly steeply; in the Rock of Ages quarry it is poorly developed; and in the upper Smith quarry it is nearly horizontal and very well developed (Fig. 1). Lineation of feldspar and quartz was first described by Balk (1927), who thus introduced to the United States the study of internal structures of igneous rocks as initiated by Hans Cloos. Balk noted that the lineation trends northeast and is arched and concluded that there were several domes of intrusion; Murthy, on the other hand, has concluded that there is a single large dome of intrusion, interrupted by septa of schist.

Origin

Murthy (1957) has summarized the evidence indicating that the Barre granite was formed by fairly quiet intrusion and by stoping. Granitization is unlikely because the granite is in sharp contact with xenoliths and country rock. Also, the country rock consists of interbeds of widely differing composition, yet the granite is homogeneous. Evidence in favor of a magmatic origin includes the finer texture of the granite at its contact, flow lines and other structures associated with a mobile fluid, and rotation of xenoliths. Forceful injection is probably of little importance, because of the absence of local deformation in the country rock.

ECONOMIC ASPECTS

Of the many granite bodies in New England, the Barre granite is one of the best known, because it yields monumental stone of the highest quality and uniformity. In the 1830's, stone reportedly from Cobble Hill was quarried for the capitol building in Montpelier, but large-scale operations did not begin until about 1875, when the Wetmore and Morse quarry was opened. By 1901, some 3000 persons were engaged in quarrying and finishing the stone (Finlay, 1902). Although several quarries were opened on Cobble Hill, all present operations are on Millstone Hill. Dale (1923, pl. 2) reproduced a map dated 1907, covering the area of Figure 1 and naming the now-abandoned quarries. Most of the stone is quarried by the Rock of Ages Corporation for monumental and building stone; waste is dumped to form the large grout piles. The only other producing company is the Wells-Lamson Quarry, which salvages the waste by crushing it. Information on the quarrying and finishing of stone was kindly supplied by Mr. Ralph Smith, Director of Public Relations, and by Mr. Cyrus Y. Ferris, Chief Engineer, both of the Rock of Ages Corporation. Through them, incidentally, it was possible to prepare Figure 1, which was traced from Sargent photograph 8003 57-102, May 6, 1957; the photograph was at a scale of 400 feet to the inch, and Figure 1 represents a reduction of 3.5 times.

Quarrying

In order to quarry the granite with least waste, quarrymen are guided by the joints (headers) and by the internal fabric of the rock (rift, lift, and hardway break). In addition, they must contend with rock pressure (internal stresses in the rock), which may cause the rock to expand locally as much as 2 or 3 inches (White, 1946). The rock pressure varies from area to

area and even within one quarry. This is most commonly a problem where there are few or no vertical fractures, and indeed, the most notable pressure problem is reported to be in the rib of rock between the upper Smith quarry and the deep Wetmore and Morse quarry, where sheeting is well developed. White discusses rock bursts in some detail, showing how they represent expansion into the quarry.

To relieve the internal stresses, the granite is first freed in large masses. The sides are cut by jetting, which consists of fuel oil burning in pure oxygen, causing a flaking of the granite. The deafening roar from this operation results from gas velocities above Mach 1. Water, which is used to cool the nozzle, also controls the dust. The jetting is more expensive than drilling but can cut a channel 30 feet deep, as opposed to the 15-foot depth of the pneumatic drill, thus freeing much larger blocks. Faces cut by jetting are smooth and streaked, in contrast with the fluted surface left by a line of drill holes. The large masses are drilled at the base by horizontal holes, and black powder lifts the masses free.

Once the mass is freed, it is broken into saw blocks by lines of drill holes that are wedged, or perhaps are shot with black powder. The drill holes alined parallel to the rift and to the lift are shallow compared with those alined parallel to the hardway break (head grain). Although the rift is generally parallel to the longitudinal joints, and the lift parallel to the sheeting, there is not a constant accordance of the joints with the internal fabric.

The saw blocks are quarried with the hardway break or head grain on one set of long faces. The block may be quarried in vertical position, with the lift the small faces, or it may be quarried in horizontal position, in which case the rift is the small faces. For special purposes, such as statues, columns, and paper rolls, blocks may be quarried with the head grain on the small face.

Saw Plant

The quarried blocks are sawed on (parallel to) the head grain in one of two ways. The gang saw, which consists of blades 1/2 inch thick, and uses chilled steel shot as abrasive, is cheaper but slower and has a tolerance of 3/8 inch. The newer saws are wire saws, which are more expensive but cut a smoother face to a tolerance of 1/4 inch. These wire saws use 60-90 mesh silicon carbide as abrasive. They are twisted, with twists reversed every 50 feet of wire. The ribbon-twisted wires are 3/16 inch in diameter, and their average wear is 5 1/2 feet of wire to cut a foot of depth. The two-strand twisted wires are 1/4 inch in diameter and they average 3 feet of wire per foot depth of cut. To increase the cutting life of a set of wires (and so to decrease the frequency of repairs), the wires are extremely long, feeding around pulleys far back of the saw plant; the 7-wire saws are 1700 feet long and the 4-wire saws are 1150 feet per wire.

In the yard by the saw plant, several types of granite are seen in addition to the Barre granite. The darker red granite, with pink feldspars, is from Wausau, Wisconsin, and the lighter red granite, colored by small reddish splotches, is from Snyder, Oklahoma. The granite from Newark, Vermont, is somewhat gneissic, coarse, and cream-gray; that from Bethel, Vermont, is white, with vague darker areas of quartz and muscovite.

Manufacturing

Though the Rock of Ages Corporation sells some stone to other manu-

facturers, it saws and finishes much of the stone it quarries. The bulk of the stone from the Smith quarry is used for building stone, but all of the stone from the Rock of Ages quarry goes into monumental stone.

Slabs from the saw plant are taken to the Craftsman Center; practically all slabs are polished on both sides (parallel to the head grain). The slabs are polished by a giant "floor polisher" using 60-90 silicon carbide; by a second one, using finer sizes, down to 600 alumina; and finally by a third stage, using tin oxide for buffing. The foreman then lays out cuts on the slab to suit the orders, and the cutter breaks the slab with hammer and splitter, taking advantage of the rift and lift directions. Sandblasting, to cut designs and roughen the stone, is done through a rubber template, using cast iron shot or 70-grit silicon carbide. Other equipment, such as a rotary diamond mill, a wire saw, and so on, are used for different effects.

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TRIPS C-1 and C-2

The Glacial Geology of Northern Vermont

The Glacial Geology of Northern Vermont

David P. Stewart *

INTRODUCTION

For the past six field seasons, the writer has participated in a surface mapping program under the joint sponsorship of the Vermont Geological Survey and the Vermont Highway Department. The work has been under the direct supervision of Dr. Charles G. Doll, the State Geologist. During this time, fourteen quadrangles covering approximately twenty percent of the total area of the state have been mapped.

Insofar as the northern section of Vermont is concerned, the major portion of the work has been in the Montpelier-Burlington Region, and this is the area to be covered by the two field trips.

It has been established that at least two late Wisconsin ice invasions covered the northeastern section of Vermont. The most recent of these invaded the Champlain Lowland from the northwest, crossed the Green Mountains and lapped upon the western flanks of the Worcester and Elmore mountains in the Stowe area.

South of the Winooski River the margin of this ice sheet is not too well marked but it seems probable that the ice moved into the Dog River valley. All of the surface till in the Champlain Valley and the Mt. Mansfield-Camels Hump region thus far mapped was deposited by this ice episode. The ice mass has been designated the Burlington lobe and the till it deposited, the Burlington till (Stewart, 1961).

The striations on the bedrock in the Montpelier Quadrangle east of Worcester Mountain and in the Barre Quadrangle east of the Dog River indicate that the last ice to cover this region came from the northeast. A dark grey, indurated till with a northeast fabric has also been found in the northern part of the Champlain Lowland. The older till has been noted at about a dozen different localities in the Burlington, Milton and St.Albans quadrangles. Here it underlies the younger, brown Burlington till. Because this till was first studied in the Shelburne area, it has been designated the Shelburne till (Stewart, 1961).

The correlation of these tills has not been definitely established. MacClintock(1958) has mapped two tills in the St. Lawrence Valley. The younger till from the northwest he called the Fort Covington and the older from the northeast, the Malone. MacClintock and Terasmae(1960) have correlated the Fort Covington till as Port Huron(Mankato) in age and the Malone as probably Cary. It is believed that the Burlington till is the same age as the Fort Covington in the St. Lawrence Valley and the Shelburne is the same as the Malone.

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Studies of the Lake Vermont shore deposits by the present survey have established the existence of a higher-than-Coveville stage of this lake episode. The shore phenomena of this stage have been traced from the southern border of the Burlington Quadrangle, in the vicinity of Hinesburg, to Georgia Mountain, due west of Milton. In this distance, approximately 25 miles, the shore features rise from an elevation of 695 feet to 750 feet. A higher-than-Coveville lake stage was identified in New York by Woodworth (1905) and he named it the Quaker Springs stage. Very little mention has been made of this stage since that date and it had not been identified in Vermont prior to the present survey.

The lacustrine deposits of the Montpelier and Camels Hump quadrangles have been mapped but, as yet, a complete correlation of these has not been possible. It has been proven that the three stages of Lake Vermont extended at least partway up the Winooski and the Lamoille valleys. It is believed that the lake level designated the Winooski by Fairchild(1916) and the Mansfield by Merwin(1908) may be the Quaker Springs stage of Lake Vermont and that this lake extended up the Winooski River to Montpelier and the Lamoille River to Morrisville. The extent of the earlier stages of Lake Vermont, the Fort Ann and the Coveville, was described by Chapman(1937).

How many lake levels higher than the Quaker Springs that occured in the Winooski valley is not exactly known. There seems to be a lake strand slightly higher than the Quaker Springs but this has not been traced to determine its full extent. The elevations of the shore phenomena range from 750 to 775 feet. It is possible that this was the level instead of the Quaker Springs that Merwin(1908) called Lake Mansfield.

Another lake level seems to occur between 800 and 850 feet in the Winooski, Stowe and Lamoille valleys. This lake has not been noted in the literature nor has it been definitely outlined by the present survey.

In the North Branch valley, north of Montpelier, evidence for a lake 1000 to 1050 feet in elevation seems to occur in the form of small deltas along tributary streams 3 to 6 miles north of Montpelier and lacustrine sands in the main valley. These deposits, however, have not been traced to any other part of the Winooski valley. It is possible that this lake level correlates with that named Lake Montpelier by Fairchild(1916) in spite of the fact that both Fairchild(1916) and Merwin(1908) did not believe that the waters of this lake stood above 900 feet.

The highest lake yet found in this region is in the Stowe valley. This lake is manifested by shore phenomena northwest of Stowe on West Hill and southeast of Morrisville on Elmore Mountain. In this area, the shore features range in elevation from 1150 to 1200 feet. This is no doubt the same strand as that which C.H. Hitchcock(1908) correlated with one stage of Glacial Lake Memphremagog. Whether or not these shore phenomena can be actually traced into the Memphremagog basin is yet to be seen. It is now believed that the lake was held at this high level by the ice of the Burlington lobe when it lapped upon the western flank of the Worcester Mountains south of Stowe and it may have drained around this ice and into a lower lake in the Winooski valley through Middlesex Notch.

The gravel terraces in the Hinesburg section of the Burlington quadrangle have been of much interest to geologists. The origin of these deposits has been debated and several genetic classifications have been suggested. The two most popular beliefs have been that the gravel was a delta deposit built into Lake Vermont by Hollow Brook or that they were kame terraces. The

present survey has determined that the gravel was originally deposited as kame terraces, and that the top surfaces and the ice-contact slopes have been subsequently modified by the wave action of the Quaker Springs and Coveville stages of Lake Vermont.

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TRIP C-1

The Glacial Geology of Northern Vermont --

Part I, The Burlington Region

Leader: D.P. Stewart

LUNCH: Box lunches will be needed for this trip and should be arranged for at the registration desk.

MAPS: The trip includes areas covered by the Montpelier, Camels Hump, Mt. Mansfield, Milton and Burlington Quadrangles. Copies of the surface geology map of the Montpelier, Camels Hump and Burlington quadrangles are included in the field trip guide. The Mt.Mansfield quadrangle has not been mapped. The trip makes two stops in the extreme southwest corner of this sheet. There are no stops in the Milton Quadrangle.

START: The party will board a bus in front of the Pavilion Hotel, Montpelier, at 7:30 a.m., Saturday, October 14, 1961.

MILES

0 The bus will depart from Montpelier via the new Inter-state Highway and U.S. Route 2 to Richmond. From Richmond the route turns north to Jericho Center and Underhill Flats and thence west to Jericho.

There are numerous interesting cuts along the new Interstate Highway to Waterbury (Montpelier Quadrangle). Most of these, however, have been grassed over. Between Waterbury and Richmond (Camels Hump Quadrangle), the road-work is in progress, but we do not stop here. The terraces along this route are mostly lacustrine. A typical cut 100 feet high will have 40 to 50 feet of varved clay below 50 to 60 feet of lacustrine sand. It has not been definitely established just how many lake levels are represented here in the Winooski valley. Three lake stages of Lake Vermont undoubtedly extended at least partway up the valley and one or two higher lakes occupied the valley before the Champlain Lowland was clear of ice.

North of Richmond (after leaving U.S. Route 2) the road climbs to the top of a sandy delta (elevation approximately 500 feet) that was built into the Fort Ann Stage of Lake Vermont (Chapman, 1937). Above the sand, till and bedrock cover the hill to the top (2 miles north of Richmond) where a second lacustrine terrace stands at an elevation of about 700 feet. A small pit in the lake sand can be observed on the left at the top of the hill.

Beyond the lake terrace, the road rises to the top of a kame terrace ($2\frac{1}{2}$ miles north of Richmond) and follows this deposit for about four miles. The road dips into a stream valley and the kame gravel can be seen on the left. The kame and kettle topography of the summit of the kame is well developed beyond the stream valley, and the bus will stop for five minutes so that those who wish can take a closer look at a kettle.

Jericho Center is built on a deposit of beach gravel and the bus will stop just beyond the village so that all can see the beach ridges on the right of the road. There are no openings in these gravels at the present time. One and one-quarter miles north of Jericho Center, the route crosses the Lee River and lake sands form the low terraces north of the river.

At Route 15, (Mount Mansfield Quadrangle) the tour will turn right and make a swing up to Underhill Flats and back so as to see the lacustrine terraces to the east of the highway before going west to STOP I. Kame terraces can also be seen to the north of Underhill Flats.

37.4 STOP I -- Gravel pit in lacustrine beach gravel (20 minutes)

STOP II - Gravel pit in lacustrine beach gravel (40 minutes)

STOPS I and II are gravel pits in the same deposit that are actually about two-tenths of a mile apart. Since the bus can drive into both pits, however, the party will board the bus at STOP I and go to STOP II. The size of the pit at STOP I gives an appreciation of the extent and depth of the deposit. The structures are much better at STOP II. The highest bar in this area is 725 feet in elevation.

The high-level lake deposits seen in this area have now been proven to be a pre-Coveville stage of Lake Vermont. These deposits (in the Jericho Center-Underhill area) were studied by the present survey in 1959. They have since been traced to the southern end of the Burlington Quadrangle (the southern limit of the survey) and as far north as Georgia Mountain, due west of Milton. This lake stage was designated the Quaker Springs by Woodworth (1905).

From STOP II the bus will continue west on Route 15 to Essex Junction (Milton and Burlington quadrangles).

From Jericho to Butlers Corners (about 4 miles) the road follows the sandy plain of the Winooski delta built into the Fort Ann Stage of Lake Vermont (Chapman, 1937). Beyond Butlers Corners (to Essex Junction) the surface material is lacustrine clay.

46.5 STOP III -- The Drury Brick-yard clay pit (30 minutes)

Brown clay over grey clay (both lacustrine) are exposed in the pit. In some places, there seems to be a pebbly material at the contact of the two colors. It has not been possible, however, to prove that the grey and the brown represent different lake stages. The brick-yard has been operated at this location for over 90 years by the Drury family. The original clay pit was at the present site of the kilns. A dense blue-grey till underlies the clay.

From STOP III the route goes south to U.S. Route 2 and then west to Spear Street in Burlington and follows Spear Street south for approximately 2½ miles to Swift Street. The route turns west on Swift Street to U.S. Route 7 and thence south to Shelburne.

Route 2A crosses the Winooski River one mile south of Essex Junction. From this point to Swift Street in Burlington, the level, sandy surface is the Delta of the Winooski River built into the Champlain Sea (Chapman, 1937). A large pit in the marine sand is located at the point where the route joins U.S. Route 2. The top of the delta in this area ranges from 300 to 340 feet in elevation.

The intersection of Spear and Swift streets is just above the marine shore. About one-tenth mile after turning west on Swift street, the street descends the old shore cliff. The terrace is well developed at this point and the bus will stop here long enough for everyone to see the cliff. Those that wish may get off the bus. The elevation at the base of the cliff is 330 feet.

62.8 STOP IV -- Two tills in stream channel (30 minutes)

Here in a small stream valley a brown till is exposed over a dark

grey till. The fabric of the brown till is northwest whereas the fabric of the black till is northeast. This is one of about a dozen where the two tills have been found exposed together. The brown till was exposed in the excavation for the new dormitory at the intersection of U.S. Route 2 and Spear Street in Burlington. The younger brown till has been designated the Burlington and the older till the Shelburne (Stewart, 1961).

The exact age of the two tills has not been definitely established. MacClintock(1958) described a younger till in the St.Lawrence Valley that he called the Fort Covington and an older till that he designated the Malone. The Fort Covington till was deposited by ice from the northwest and the Malone by ice from the northeast. These two tills have been tentatively correlated as Mankato(Port Huron) and pre-Mankato, probably Cary, respectively (MacClintock and Terasmae, 1960).

It is believed that the Burlington and Shelburne tills will correlate with the Fort Covington and Malone tills of the St.Lawrence Valley(Stewart, 1961).

STOP V -- Lunch(45 minutes)

After lunch, the tour will continue south on U.S. Route 7 to the foot of Jones Hill(3.4 miles) thence east on the Charlotte-Hinesburg road to East Charlotte(2.3 miles) and then south for a distance of 2.3 miles.

The route here crosses the lake plane of Lake Vermont. The surface material is a bouldery lacustrine clay. The source of the boulders is probably two-fold: (1) They were ice rafted and (2) they are residuals from underlying till.

70.8 STOP VI -- Stream cut along Lewis Creek two and three-quarter miles northeast of North Ferrisburg (one hour)

This stream cut probably contains more glacial geology than any other exposure in northwestern Vermont. It is not possible at this time to give a complete explanation of all that occurs here.

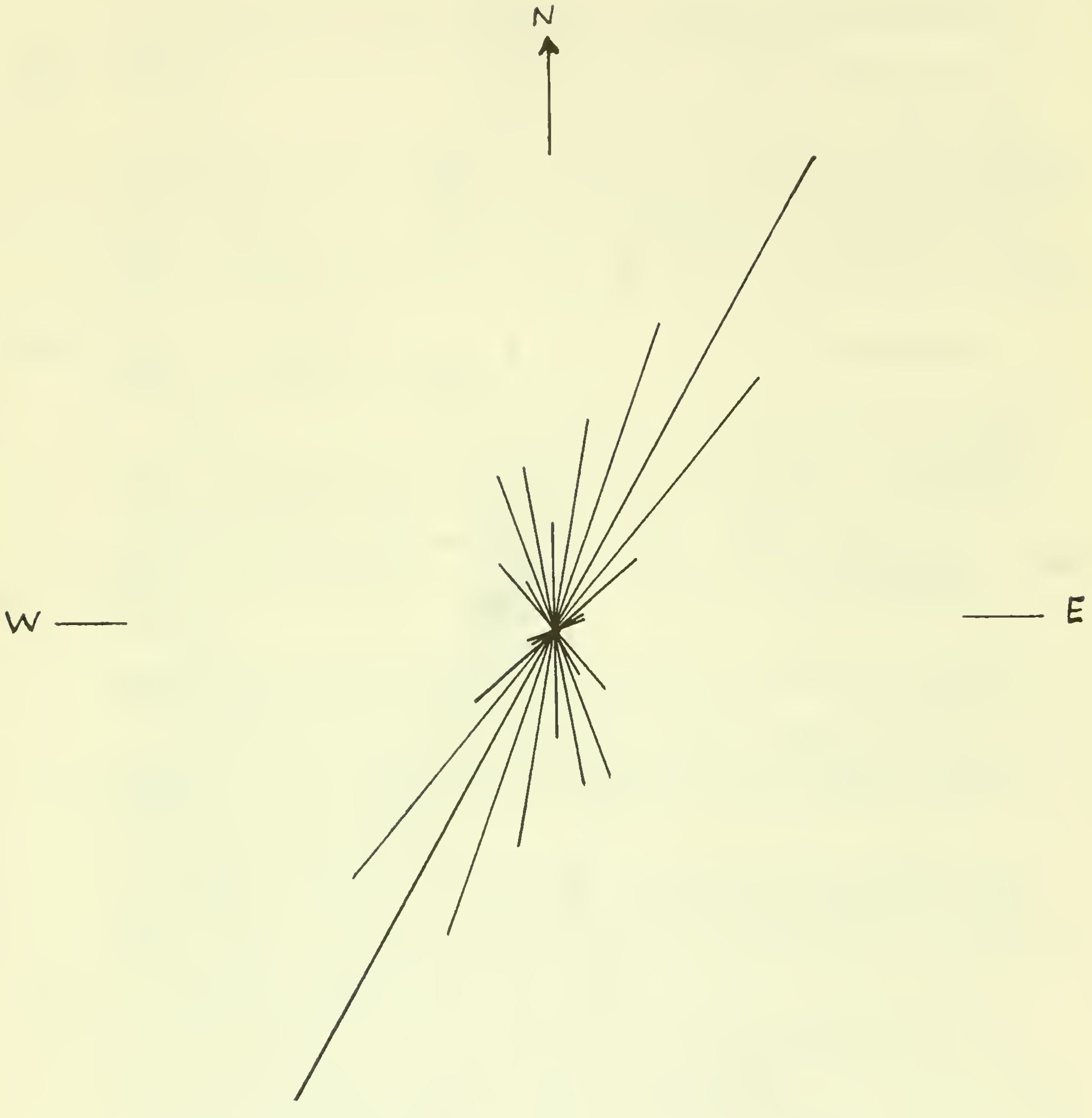
The two tills seen at STOP IV are also present in this cut. Overlying the brown till are the brown lacustrine clays of Lake Vermont.

The most interesting aspect of this cut, however, is the occurrence of an older varved clay that is overlain by the Burlington till. It is assumed that the lake that deposited the varves followed the retreat of the ice that deposited the Shelburne till. To the writer's knowledge, this is the only reported occurrence of a pre-Lake Vermont lacustrine deposit in the Champlain valley. The contact of the varves and the overlying till is interesting inasmuch as the varves are distorted at the top and some varved material has been forced up into the overlying till.

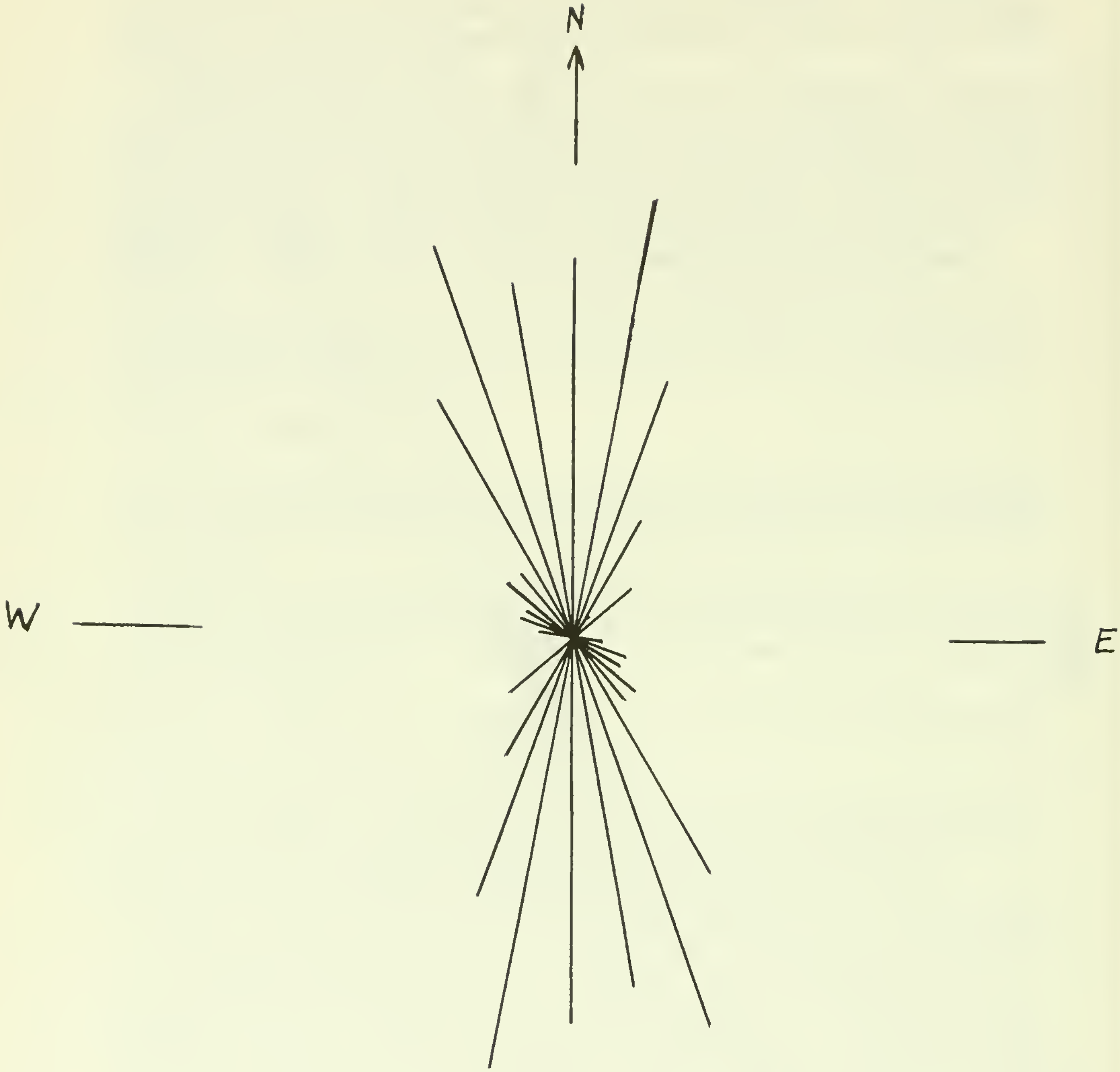
From STOP VI the bus will return to East Charlotte and proceed east on the Charlotte-Hinesburg road to Route 116 at Hinesburg. Thence we go south on Route 116 for a distance of 7.3 miles to STOP VII. In this distance we pass by the Hinesburg gravel terraces and several gravel pits can be seen from the road. The tour will return to two of these pits.

84.2 STOP VII -- The Quaker Springs shore and the Hinesburg gravel terraces (15 minutes)

Looking south from STOP VII one can see the Quaker Springs shore



Fabric of the Shelburne Till. Taken along a stream channel one and one-half miles south of Shelburne Village (Stop IV).



Fabric of the Burlington Till. Taken from excavation for University of Vermont Residence Hall at U. S. Route 2 and Spear Street in Burlington Striations on the bedrock under the Till Trend N15°W to N30°W.

terraces at an elevation of 695 feet. The shore features can be traced northward to the top of the Hinesburg gravel terraces. Looking north from STOP VII, the level tops of the gravel terraces can be noted.

From STOP VII the tour will return (North) on Route 116 to the gravel terraces and visit two gravel pits (STOP VIII and STOP IX).

88.3 STOP VIII -- Gravel Pit in Hinesburg Gravel terraces (20 minutes).

The genetic classification of the Hinesburg gravel terraces has been debated by many geologists in the past. The present survey agrees with the conclusion of Chapman (1937) that these terraces are composed of kame gravel. The confusion has been caused by the fact that the kame terraces have been modified by the subsequent wave action of Lake Vermont. The gravel pit here at STOP VIII shows the ice contact structures of the kame gravel.

88.6 STOP IX -- Gravel Pit in Beach Gravel at the top of the Hinesburg Gravel Terraces (30 minutes).

STOP IX is in the same gravel terrace as STOP VIII and is located four-tenths mile north of it. Here at STOP IX, however, the gravel pit is at the top of the terrace and the beach gravel of the Quaker Springs stage is exposed. If the lower pit at this location is not too badly slumped, one can see the westward dipping beds of the gravel that was carried out over the terrace. These dipping beds accounted for the earlier arguments that these gravel deposits were deltaic.

Because of the polygenetic origin of these gravels, it seems more appropriate that they should be referred to as the Hinesburg gravel terraces and not the Hinesburg kame terraces.

From STOP IX, the tour will return south on Route 116 to South Hinesburg and then travel east through the Hollow Brook valley to Huntington. Hollow Brook has cut a valley into the gravel terraces just east of South Hinesburg and a large gravel pit can be seen on either side of the road.

Those who have contended that the Hinesburg gravel terraces were deltaic have proposed that the gravel was deposited by Hollow Brook. The wide, flat bottom of the valley and the kame terraces on either side, however, suggest that the valley was filled with ice at the time that the kame gravel was deposited.

Two and one-half miles east of South Hinesburg a beaver pond is located in Hollow Brook. This can be seen on the right.

If the weather is clear, a beautiful view of Camels Hump can be seen as the Huntington River valley is approached.

At the Huntington River, (Camels Hump Quadrangle) the tour proceeds down stream on the Huntington River Road to Jonesville.

Trout fishermen note the cool, clear water of the Huntington River.

98.2 STOP X -- The Huntington River Gorge (30 minutes, if we aren't running late)

The Huntington Gorge was carved by the pothole action of the Huntington River. The potholes are numerous and of various sizes.

From STOP X the tour proceeds to Jonesville and east on U. S. Route 2 and the Interstate Highway to Montpelier.

STOP XI -- Montpelier

TRIP C-2

The Glacial Geology of Northern Vermont --

Part II

Elmore Mountain, Stowe Valley and Smugglers Notch

Leader: D.P. Stewart

LUNCH: Box lunches will be needed for this trip. Arrangements for a lunch should be made at the registration desk.

MAPS: The trip includes areas in the Montpelier and Hyde Park quadrangles. A copy of the surface geology map of the Montpelier Quadrangle is included in the Field Trip Guide. The Hyde Park Quadrangle has not been mapped. Since there are five stops in the Hyde Park Quadrangle those attending the field trip may wish to bring this topographic sheet.

START: The party will depart from the Pavilion Hotel in a car caravan at 7:45 a.m., Sunday, October 15, 1961.

MILES The car caravan will leave the hotel heading east on State Street and turn north on Elm Street and proceed north out of Montpelier. The road continues north through the valley of the North Branch of the Winooski River to Lake Elmore.

The terraces along the valley wall as we leave the Montpelier city limits are built of lacustrine clays and sands. Varved clay can be noted in the base of the exposure about one-half mile north of the intersection of State and Elm streets.

The lake terraces give way to kame terraces approximately three miles north of Montpelier. The road climbs to the top of the terraces and continues over the terraces for two and one-half miles to Putnamville.

At the top of the gravel terraces, the Wrightsville Dam can be seen on the right. This is an earth-fill, flood control dam that controls the water of the North Branch.

Beyond Putnamville, there are several small sand and gravel terraces in the North Branch Valley that are believed to be delta deposits that were built into a lake, or a series of lakes, that once occupied the valley. It is now the opinion of the writer that these were built into small ice-contact lakes that existed during the melting of the last glacier. The road crosses the first and largest of these deposits at Worcester. Note the level top of the deposit. It is probable that a part of this deposit is outwash but no pits exist that allow an examination of the deeper materials. A small pit in delta gravel is opposite the cemetary in Worcester. Elevation 780 feet.

The striations on this side of the Worcester Mountains trend N 10°E to N 20°E and therefore the last ice in this section was propably the Shelburne glacier of a pre-Mankato substage, probably Cary. It is therefore believed that these lake deposits may antedate those of the western part of the Winooski Valley.

From Worcester we proceed 2.8 miles north to STOP I(Gravel pit on the left side of road).

12.0 STOP I -- Gravel pit in lacustrine gravel (30 minutes)

This deposit exemplifies the small deposits found in the North Branch valley. Delta structure is not too well developed here, but beach characteristics are quite obvious. Elevation 830 feet.

From STOP I continue north to Elmore Lake. Several small patches of lake sand can be noted along the road for five miles. At the time of the writing of this guide (August, 1961), road construction was in progress in this area and several openings were to be made in the lacustrine materials. The terraces four miles north of STOP I are at an elevation of approximately 1000 feet. This level seems to be the best developed in the North Branch valley and three small deltas of tributary streams occur three to six miles north of Montpelier at elevations of 1010 to 1030 feet.

Six and one-half miles north of STOP I two beaver dams can be seen on the left. A beaver house can also be seen.

23.5 STOP II -- Elmore Lake State Park (15 minutes)

Elmore Lake is a scenic example of a kettle lake. Note: Elmore Lake is located in the Hyde Park Quadrangle. This area has not been mapped and, therefore, no map is included in the guide. Stops III, IV, V, and VI are in this quadrangle.

From Elmore Lake the caravan will continue north and northwest on the road to Morristown. One mile from Elmore Lake turn right onto a graveled road and STOP III is one-half mile.

25.7 STOP III -- Frontal Moraine (15 minutes)

As all New England geologists know, frontal moraines are rare in this region. The small ridge seen here is the best developed moraine yet found in this section of Vermont. It is believed that this will prove to be the terminal moraine of the Burlington glacial lobe from the northwest.

From STOP III continue on the road to Morrisville. The morainic ridge can be seen to the right of the highway.

Note the round barn about one mile beyond STOP III.

Two and one-half miles west of STOP III the caravan will turn left (onto the only hard surfaced road that turns left), then immediately to the right (follow hard surfaced road) and follow this road to the Morrisville Armory. A gravel road immediately east of the armory leads into a large gravel pit.

29.6 STOP IV -- Gravel pit in beach (delta?) gravel (30 minutes)

The gravel here is definitely lacustrine. The elevation of the surface is approximately 775 feet. Although the deposit has not been traced down the river, it is suspected that this will prove to be a delta that was built into the Quaker Springs Stage of Lake Vermont. The level surface of the gravel extends northward through the area of the Country Club.

From STOP IV, we will return (toward Elmore Lake) to the Elmore Mountain Road. This road is gravel and is the first right after returning to the Elmore Lake-Morrisville road. The mountain road follows the top of a kame terrace. The caravan will turn right six-tenths mile after entering the gravel road and go into a gravel pit.

32.1 STOP V -- Gravel pit in kame gravel (15 minutes)

This kame terrace is one of three large terraces that are found on the east side of the Stowe Valley between Morrisville and Waterbury. It is believed that these terraces were formed at the terminus of the Burlington ice lobe as it began melting back from Elmore and Worcester mountains.

From the gravel pit, continue south on the Elmore Mountain Road for two and one-half miles, turn right on Delano School road. STOP VI is four-tenths mile.

35.0 STOP VI -- Lacustrine off-shore bar (20 minutes)

Here is a gravel bar built by the wave action of a high-level lake in the Stowe Valley. The highest point on the bar is just above the 1140 foot contour. The deposit was no doubt made off-shore. Shore phenomena of this same lake level will be seen at STOPS VIII and IX. This is undoubtedly the lake level that C.H. Hitchcock(1908) correlated with one of the stages of Lake Memphremagog but whether or not it can be traced into the Memphremagog basin is yet to be determined. Merwin(1908) and Hitchcock(1908) suggested that this lake had an outlet through the divide between the Dog and White rivers at Roxbury and Fairchild(1916) assumed it drained southward through Williamstown Gulf. The present survey has found no evidence of such a high-level lake in the Winooski or Dog river valleys or Williamstown Gulf. The data collected to date indicates that the Stowe Valley was dammed by ice (Burlington lobe) south of Stowe and that the water probably drained into the Winooski valley via Middlesex Notch.

After STOP VI continue west on the Delano School Road to its end and turn left on the hard surfaced road. This road intersects Route 100 and the caravan will follow Route 100 into Stowe.

41.0 STOP VII -- Lunch (45 minutes)

Following lunch the caravan will continue on Rt. 100 to the north end of Stowe. Turn right on West Hill Road at the Chicken Farm and follow the gravel road two miles to STOP VIII.

44.6 STOP VIII -- Gravel pit in beach gravel (30 minutes)

The gravel here, at elevation 1110 feet, marks the same lake level as the bars at STOP VI. The size of this deposit seems to indicate that the lake existed for a rather long period of time and does not support a conclusion that it was made by a small, local, ice-contact body of water.

From STOP VIII, continue on the West Hill Road, keeping left at the next two road intersections, for one mile and turn right at third intersection. STOP IX is one-tenth mile up the hill.

45.7 STOP IX -- Beach ridges (15 minutes)

The highest beach ridge in this group is 1170 feet. Same lake as STOP VI and VIII.

After STOP IX, we turn around and descend the hill to Stowe. Turn right on Route 108 and continue to Smugglers Notch.

Lake sediments can be noted on the right four miles after the Route 108 intersection. These deposits are at an elevation of approximately 900 feet and have not been correlated with lake levels in the Stowe Valley.

Kame terrace gravels are rather common on this side of the mountain. They can be seen at points five miles and eight and one-half miles beyond the intersection where the caravan entered Route 108.

Near the summit of Smugglers Notch, the road is winding and "winds" around large ice-riven boulders from the almost-vertical sides of the mountain. Undoubtedly the riving by the ice dates from the Pleistocene but a definite estimate of what percentage of the boulders are post-glacial cannot be made.

Note the Big Spring near the top of the mountain. We will stop for a drink (of water).

57.0 STOP X -- Smugglers Notch -- End of trip.

TRIPS D-1 and D-2

Structural Geology of Northern Vermont

STRUCTURAL GEOLOGY OF NORTHERN VERMONT

By John G. Dennis

The geologic structure of Northern Vermont is simple in its broad outline, but very complex in detail. The stratigraphic units involved are shown in Table 1. There is a facies change from a miogeosynclinal dolomite-quarzite-shale sequence in the west to a typical eugeosynclinal greywacke-volcanics sequence in the east. This has been well discussed by Cady (1960).

The rocks are revealed in a number of broad synclinoria and anticlinoria (Fig. 1). From west to east they are:

1. The St. Albans synclinorium, bounded in the west by the Champlain thrust and in the east by the Hinesburg thrust with its distinctive klippen. (See Fig. 2). The stratigraphic sequence on its west limb has been known as the "Rosenberg Succession". (Clark, 1934, Shaw, 1958).

2. The Enosburg anticlinorium; the stratigraphic sequence within this structure has been known as the "Oak Hill succession" (Clark, 1934, Booth, 1950).

3. The Richford - Cambridge synclinal zone;

4. The Green Mountain anticlinorium whose interfingering stratigraphic units are grouped together as the Camels Hump group.

5. The Gaspe-Connecticut valley synclinorium; which carries the Silurian and later rocks of the St. Francis group. The latter is complicated by a prominent anticlinal zone in its core, the Willoughby arch.

The major structures cannot normally be outlined directly, but only by careful mapping which must take into account the facies changes from west to east. In addition, the analysis of minor structures has proved to be a very rewarding structural tool which has shed some considerable light on the nature of the tectonic movements at the time of the Acadian orogeny.

Figure 3 shows two cross-sections which in diagrammatic outline indicate the pattern of the three cleavages and schistosities which have been observed in the area. Critical field relations have permitted their classification by relative age into S_1, S_2 and S_3. Associated minor folds can be identified and classified in a similar three-fold age sequence. One exceptional outcrop, which will be visited, shows all three cleavage and fold generations in one exposure. Genetically, S_1 is an early schistosity, of the "axial plane" type in the west, and predominantly parallel to the bedding in the east. A slip cleavage, S_2, is directly associated with the Willoughby arch, and probably marks flowage away from the crest of the arch. S_3, also a slip cleavage, is most prominent in the Green Mountain anticlinorium, but has been observed sporadically throughout the area. It is always steep to vertical, and its associated minor folds and lineations are quite characteristic.

The nature of the eastern boundary of the area is still somewhat controversial. Three interpretations are shown in Fig. 4. A discussion is given in Eric and Dennis (1958).

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The following relevant bulletins of the Vermont Geological Survey are about to go to press:

Dennis, J.G., Enosburg and adjacent areas, Vermont

Konig, R.H., Plainfield quadrangle, Vermont

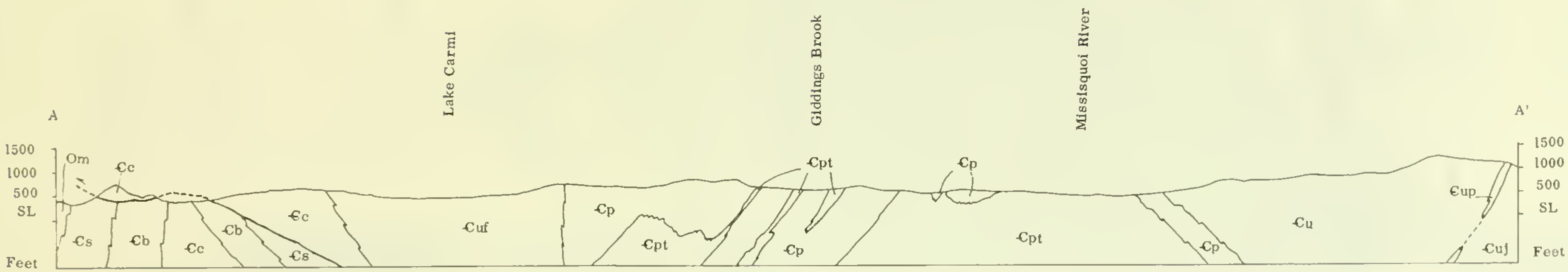
Konig, R.H. and Dennis, J.G., Hardwick quadrangle, Vermont

Stone, S.F. and Dennis, J.G., Milton quadrangle, Vermont.

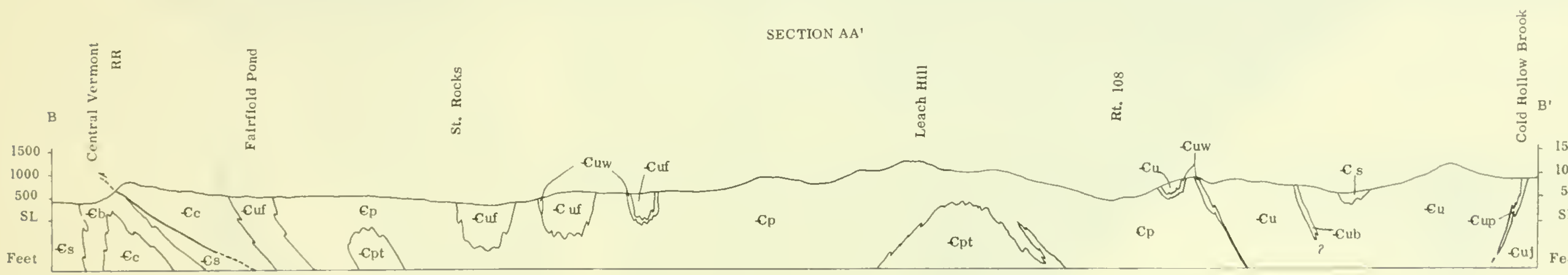
Table 1:

Sequence of Geologic Events in Northern Vermont.
(East of Champlain Thrust)

U. Triassic	Late Volcanism and Fracturing	
Mississipian and U.Devonian	Acadian Orogeny	
	West of Green Mountains	East of Green Mountains And Green Mountains
Devonian and Silurian	Not Preserved Taconic Movements. (Little Evidence)	Gile Mountain Formation Waits River Formation Barton River Mem. Ayers Cliff Mem. Northfield Formation (=? Meetinghouse Slate) Shaw Mountain Formation
Ordovician	Morses Line Slate	Missisquoi Formation Cram Hill Mem. Moretown Mem. Umbrella Hill Mem. (=? Albee * Ammonoosuc Formations) Stowe Formation
Cambrian	Sweetsburg Formation Bridgeman Hill Formation	Ottauquechee Formation
	Cheshire Formation (= Upper Gilman of Clark)	
Pre-Olenellus	Underhill Formation Fairfield Pond Phyllite White Brook Dolomite Pinnacle Formation Tibbit Hill Volcanics	Underhill Formation Camels Hump Group Jay Peak Formation Hazens Notch Formation



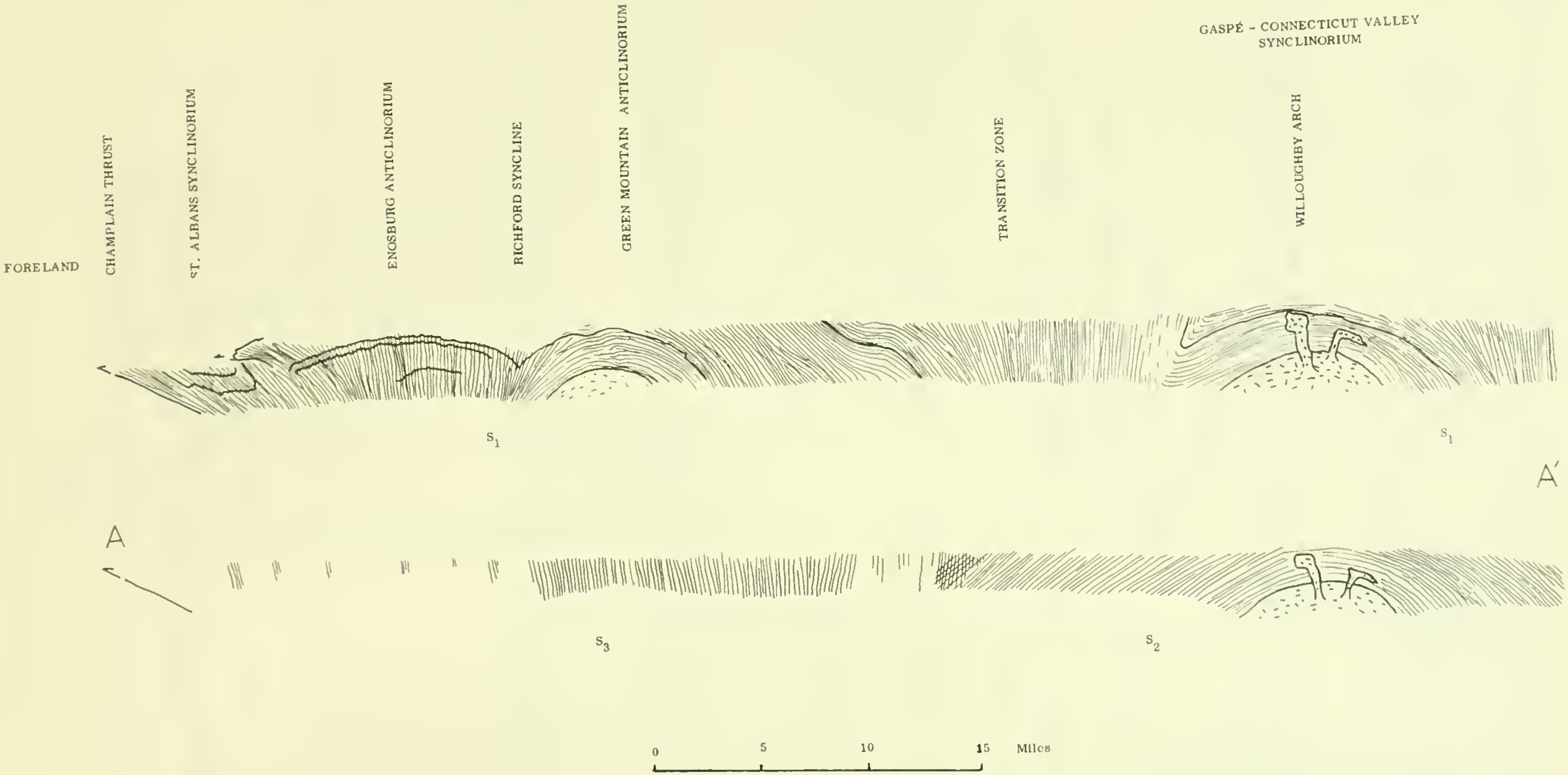
SECTION AA'



SECTION BB'

LAKE CHAMPLAIN—CONNECTICUT RIVER

VERMONT



FORELAND
CHAMPLAIN THRUST
ST. ALBANS SYNCLINORIUM
ENOSBURG ANTICLINORIUM
RICHFORD SYNCLINE
GREEN MOUNTAIN ANTICLINORIUM
TRANSITION ZONE
WILLOUGHBY ARCH
GASPÉ - CONNECTICUT VALLEY SYNCLINORIUM
A
A′
S1
S1
S3
S2
0
5
10
15
Miles

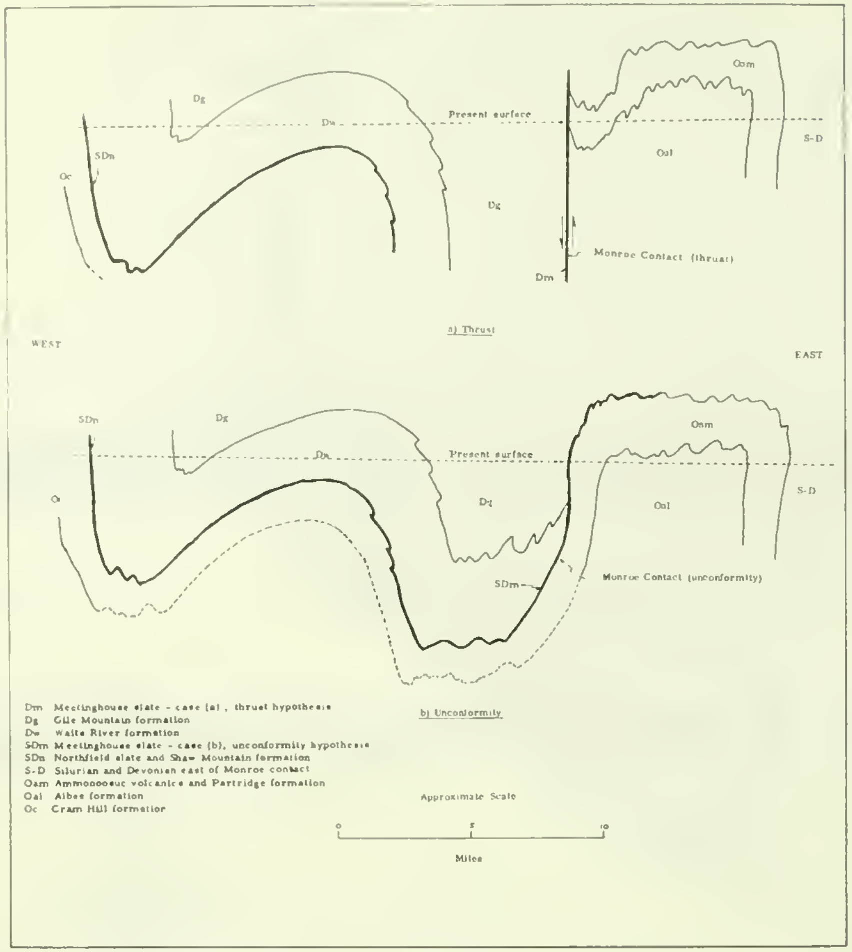
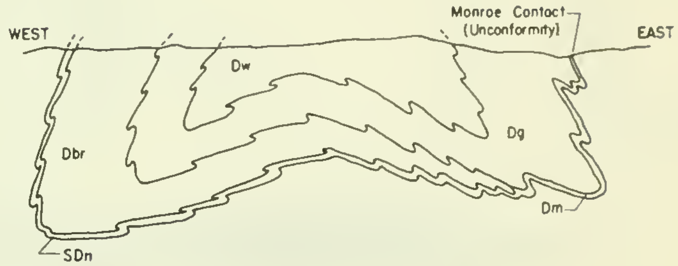


Figure 13. Diagrammatic cross-sections, illustrating the two main hypotheses for the structural significance of the Monroe contact.



Dw Waits River formation
Dg Gile Mountain formation
Dbr Barton River formation
SDm Meetinghouse slate
SDn Northfield slate

0 5 10 15 Miles

Figure 14. Diagrammatic cross-section, illustrating another interpretation of the regional structure. Modified from Murthy (1957, pl. 3).

TRIP D-1

Traverse across the Green Mountains and Foothills

Saturday, October 14, 1961, 7:30 A.M.
Assemble in bus on State Street in front of State Capitol

Leaders: J.G. Dennis and Ballard Ebbett

0.0 St. Albans town square. Log begins here. Proceed north along U.S. 7.

0.8 Fork right; Vt. Rt. 105 east.

1.4 Aldis Hill klippe on right; Hinesburg thrust escarpment ahead.

2.9 STOP 1 - Enter yard of white farmhouse. Outcrop about 200 feet southeast of farm house, in meadow: west-facing fold in Sweetsburg formation; horizontal cleavage (s_1).

4.5 Turn right on dirt road.

5.1 STOP 1a - Omer Bourdeau farm. Hillside east of farm has good outcrops of Bridgeman Hill formation. Traverse directly uphill leads to Hinesburg thrust and Cheshire formation. Return to Rt. 105.

5.8 Turn right; proceed northeast along Rt. 105.

6.2 Cross RR track. Flat country here mainly underlain by Ordovician Morses Line slate.

9.3 Fork left onto dirt road (i.e. proceed straight off bend, away from Rt. 105). Outcrop of Hungerford slate (= Upper Sweetsburg formation) on left. NO STOP.

10.0 Proceed straight (=right fork).

12.5 Cross bridge over Missisquoi River; enter East Highgate.

12.6 Turn left along VT. Rt. 78; proceed along Missisquoi River.

12.8 Turn right on road to Franklin; follow pavement.

13.0 Fork right.

13.3 Cross RR tracks. Good traverse across Oak Hill sequence to right. NO STOP. Proceed north along dirt road. Road now runs parallel to strike.

18.1 Turn left in Franklin Village.

18.4 Turn left: proceed along VT. Rt. 120 (Note: this route number may be changed in the future).

19.6 STOP 2 - Outcrop of Dunham dolomite (member of Bridgeman Hill formation). Interesting cleavage relationships. Turn back along Rt. 120, towards Franklin.

20.5 STOP 2a - Follow path in pasture westward toward Bridgeman Hill. Cheshire quartz-graywacke of klippe overlying autochthonous Dunham dolomite.

20.7 Turn left onto dirt road at four corners.

21.35 STOP 3 - Park at Cooper farm. Good outcrops of Cheshire on left. Outcrop of Dunham limestone in meadow, 600 feet northeast of farmhouse: interesting minor thrust showing cleavage control. Return to four corners north of Franklin Village.

21.95 Turn left at four corners; proceed along paved road.

23.4 Approximate location of gradational contact between Cheshire quartz-graywacke and Fairfield Pond phyllite.

24.3 Lake Carmi on right.

26.7 East Franklin; Turn right (follow pavement).

27.9 STOP 3a - West Berkshire cross-roads. Park at cross-roads, walk south to bridge over Pike River. Folded band of White Brook dolomite between Fairfield Pond phyllite above and Pinnacle formation below. From cross-roads proceed straight (southeast) toward Berkshire. Road now traverses alternation of Pinnacle graywacke (high ground) and Tibbit Hill volcanics (low ground).

28.5 STOP 4 - Pull well off road in dangerous bend. Roadcut on left reveals one of the best exposures of Pinnacle graywacke in the area. Interesting development of S_1 cleavage. Large clastic microcline crystals.

30.7 Turn left toward Richford.

33.6 STOP 5 - at elevation 642. Exposure on left of road. Cross-bedded Tibbit Hill, perhaps current-laid tuff.

35.7 Sharp right turn into Richford (follow pavement).

36.2 Turn right at stop light, and cross Missisquoi river. Good outcrops of Underhill phyllite in river. NO STOP.

36.5 Fork left along Rt. 105 east.

40.2 Continue along Rt. 105 (fork right).

45.9 STOP 6 - Road cut on right. Park where small trail turns right just past exposure. S_1 and S_3 deformation in Hazen's Notch formation. LUNCH.

46.4 Good early folds on right.

47.8 Summit. Long road cut in Hazen's Notch formation.

53.2 Turn right, proceed along Rt. 101.

57.6 Troy. Turn left, proceed along Rt. 100.

63.6 Fork right, i.e., proceed straight, along Rt. 14.

68.6 Turn right; stay on Rt. 14.

69.1 Fork right; stay on Rt. 14.

81.8 Albany. Turn left, proceed along dirt road toward South Albany (load limit 24000 lbs.).

82.3 Turn right.

83.1 STOP 7 - Road cut in Ayers Cliff marble. Good S_2 cleavage and related folds. "Irasburg conglomerate" pebbles. Return to Albany.

84.4 Albany. Turn left, proceed south along Rt. 14.

95.4 STOP 8 - Sand pit on right of road. Exposure showing all three generations of cleavages and related folds. This is a key exposure for the tectonics of Northern Vermont.

100.1 STOP 9 - Park in side road to right immediately south of exposure. Road cut showing the two generations of slip cleavage and related folds with good three-dimensional views. Please do not remove folds, except those that can easily be pried loose by hand.

101.1 STOP 10 - Intersection, Routes 14 and 15. S_3 deformation superimposed on S_2 deformation. Proceed east along Rt. 14/15.

101.9 STOP 11 (If time permits). Small exposure of Northfield slate showing typical development of S_2.

103.0 Turn right along Rt. 14 toward Montpelier. End of first day's logged trip.

NOTE: In case of delay, "a" stops may be omitted.

RETURN TO MONTPELIER

TRIP D-2

Bedding, cleavage, and minor fold relations in vicinity of Brownington syncline and Willoughby arch; Monroe Line

Sunday, October 15, 1961, 8:00 A.M.
Leave in private cars headed east on State Street in front of State Capitol

Leaders: J.G. Dennis and Ballard Ebbett

0.0 Montpelier. East on U.S. Rt. 2.

5.9 East Montpelier. North on Vt. Rt. 14.

20.3 STOP 1 - 0.3 miles north of Woodbury. Park on left side of road near old house nearly hidden by thick growth. Exposure of Waits River fm. which shows relations between bedding and S_1 and S_2 cleavage. One S_2 fold near a large granite dike.

25.5 Hardwick Village.

25.8 STOP 2 - Through Hardwick Village, left at Hardwick Inn, left just beyond State Liquor Store, left at next fork, left at stop sign - down steep grade. Park in front of Suburban Gas Dealer office. Exposure of Waits River formation in bed of Lamoille River shows relations between bedding and S_1 and S_2 cleavages and folds. Excellent example of disharmonic folding.

26.1 Return to Hardwick Inn. East on Vt. Rt. 15.

28.4 Left onto Vt. Rt. 16.

32.4 STOP 3 - Park on right side of road. Exposure of Waits River formation which shows folds and cleavage near crest of a moderately plunging large minor fold.

35.5 Exposure of Waits River formation which clearly shows strike and dip of bedding.

39.1 Near speed zone signs for Barton Village, left onto road across concrete bridge.

39.7 STOP 4 - Pass Orleans County Fair Grounds. Park just beyond concrete bridge over Roaring Brook. Cross Roaring Brook on foot and go up brook along dim path for 1500 feet. Exposure of Waits River formation shows bedding, S_1 and S_2 cleavage and folds, and boudinage on spectacular glacially smoothed surface.

40.3 Return to Vt. Rt. 16. Left toward Barton.

41.2 In center of Barton, at Park Restaurant, right onto U.S. Rt. 5, left onto Vt. Rt. 16 which crosses railroad tracks.

43.8 At hill crest, exposure of granodiorite with inclusions of contact-metamorphosed Gile Mountain formation. Their attitude conforms with that of region.

48.3 North shore of Lake Willoughby, right onto Vt. Rt. 5-A.

51.9 STOP 5 - East shore of Lake Willoughby. Park at foot of Waterfall on left side of road. Excellent exposure at waterfall of granodiorite and associated aplite and pegmatite dikes. North along road are large exposures which show excellent contact relations between Gile Mountain formation and granodiorite. Calcsilicate minerals occur in many of the Gile Mountain beds.

53.7 STOP 6 - LUNCH Stop. Southeast shore of Lake Willoughby. Park on left side of road near restaurant. Contact relations of granodiorite with Waits River formation are clearly seen on huge cliff high on Mt.Pisgah.

60.1 West Burke. Straight on U.S. Rt. 5.

67.3 Lyndonville. South on U.S. Rt. 5.

70.1 Left onto gravel road immediately south of Redwood Motel.

70.3 STOP 7 - Turn right at fork. Park in front of large red building. Walk through Power Plant to bed of Passumpsic River where excellent relations are seen between bedding S_1 and S_2 cleavages and folds in Waits River formation.

70.5 Return to U.S. Rt. 5. Right toward Lyndonville.

72.2 After crossing railroad tracks, sharp right onto paved road along north bank of Passumpsic River.

73.8 Right onto paved road to Concord.

77.8 STOP 8 - Park in dirt road on left side of road just beyond exposure. S_1 and S_2 cleavages and folds are clearly shown in Gile Mountain formation.

78.5 Left onto U.S. Rt. 2.

78.8 STOP 9 - Pass cemetery. Park in driveway of Guest House on left side of road. On foot cross pasture to hillside where exposures of Gile Mountain formation show relations between bedding and S_1 and S_2 cleavage folds.

83.3 Pass through Concord. Left onto gravel road to Kirby (sign).

84.2 STOP 10 - Park on right side of road near crest of grade about 0.1 miles beyond iron-railed bridge. In streambed Meetinghouse slate and Albee formation lithologies are interbedded. "Monroe Line".

85.1 Return to U.S. Rt.2 and bear right onto it.

91.7 Amie's Restaurant. Junction of U.S. Rt. 2 and Vt. Rt. 18. Bear sharp left up steep grade.

92.2 STOP 11 - Park in Graves schoolyard on right side of road. Exposure of Gile mountain formation which shows bedding, S_1, S_2, S_3 cleavages and S_2 folds. Some of the S_2 folds are well developed chevron folds.

END OF TRIP

Fig 1
SECTION IX
From Newbury to Valcour Island N Y

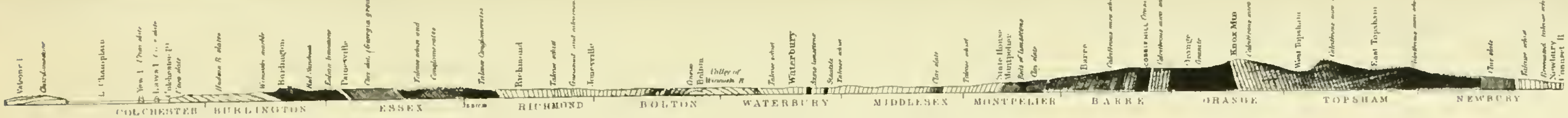


Fig 2
SECTION VIII
From Newbury to Bridport

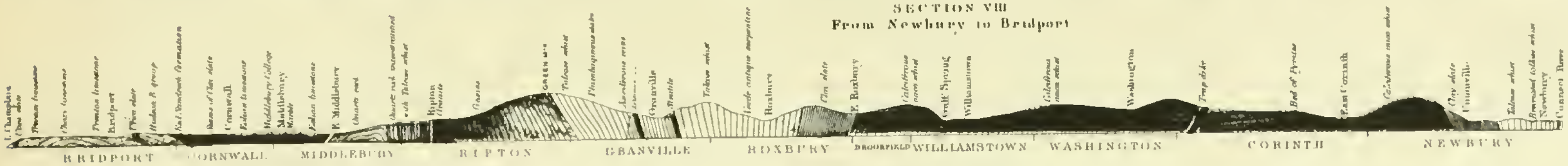


Fig 3
SECTION VII
From Thetford Vt to Lake George N Y

Fig 4
SECTION XIII
From Canaan Vt to Rouses Point N Y

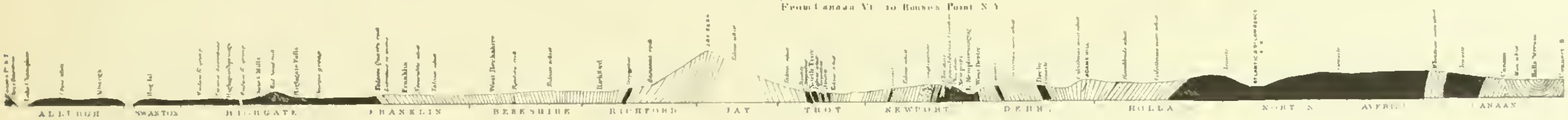


Fig 1
SECTION X a
From Lunenburg to Burlington

Fig 5
SECTION X
From Mt Washington N H to Charlotte Vt